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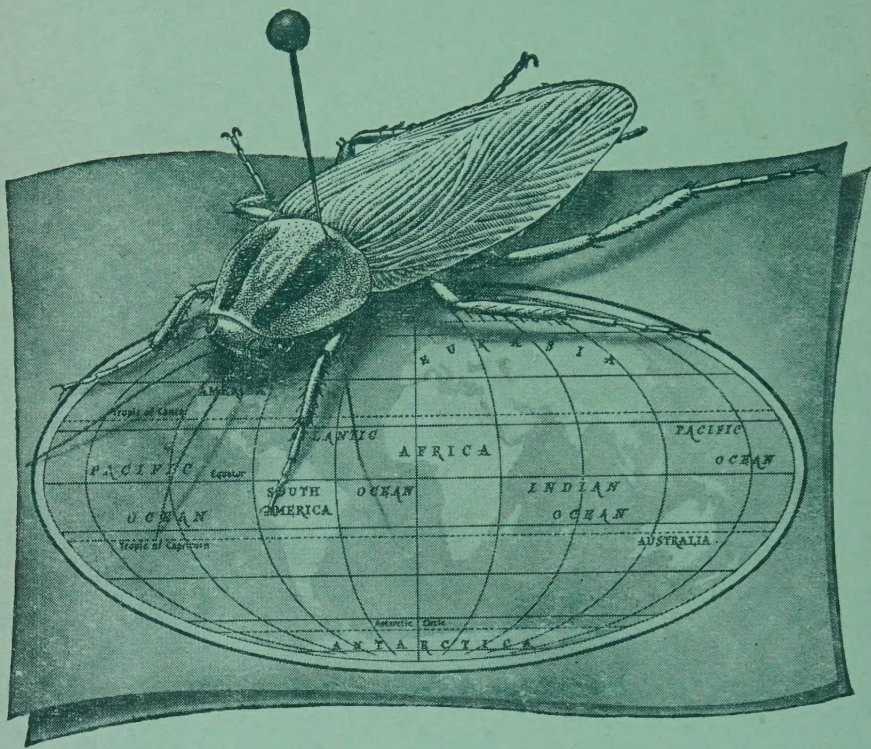

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Agricultural Settlement Schemes in the Belgian Congo

R. de Coene

Director, INÉAC Research Station, Bambesa, Belgian Congo*

During recent years, agricultural settlements have been developed on a large scale in the Belgian Congo. They have been established on various systems and in very different ecological regions. In this article, particular consideration will be given to the settlements based on the corridor system, situated in the equatorial forest of the Congo basin, and especially those located on its southern and northern limits, in the tropical rain forests bordered by anthropic grass formations.

AGRICULTURE BEFORE THE SETTLEMENTS

To understand better the importance of the problem, the necessity for this land organization, and its advantages, it is necessary to give a brief account of the previous native agricultural methods. Before European colonization, agriculture merely satisfied the barest needs of the people. In the nomadic ' Bantu system ', which was customary with the natives of the central basin, after clearing and burning the forest but without any ploughing or clearing of roots and stumps, interplanted crops were grown until some decrease in yield was apparent.

The field would then be given up to a long bush fallow restoring the chemical, physical and biological characteristics of the soil. This method (shifting cultivation) was perfectly adapted to the heavy rain forest, particularly in the case of food crops such as cassava, bananas and yams, since in these forests inhabitants were scattered and sparse, and the amount of land available was large.

On the other hand, the Sudanese and Bantu populations of the northern and southern limits of the great forest, whose diet consisted mainly of cereals (maize, sorghum, millet), were used to cultivate in a much more destructive way; never reclaiming new fields before the old ones were completely worn out, they would only allow a grass fallow which the annual fires would soon turn into savannah.

European administration gave rise to an ever-increasing destruction of the forest cover: intense agricultural propaganda, the necessity to produce more food for the towns, and the introduction into the rotation of economic crops (cotton, rice, groundnuts) resulted in larger surfaces being worked by the farmers. The latter, however, to lighten the hard work of reclaiming new fields, began to clear fallows too soon or to lengthen considerably the cropping of the same area. In some cases these bad practices were necessitated by a shortage of farming land.

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Thus there could be observed:

(1) A more and more marked deterioration of the soil; due to over-cultivation without supply of organic or mineral matter and to the fact that the fallow periods were shortened, thus preventing any soil regeneration. Moreover, along the southern and northern limits of the Congo basin, the forests consist partly of deciduous species which under the influence of the tropical climate defend themselves poorly against the progress of the savannah, the yearly burning of which prevents, even in the case of long-term grass fallow, restoration of the initial fertility.

(2) An extension of the cultivated area without corresponding increase in yield; for the farmer has at his disposal only primitive tools (hoe and machete), limiting his possibility not only of settlement but also of normal maintenance of the crops.

(3) An ever-growing fragmentation of the fields due to the search for fresh fertile soils, thus increasing the nomadic way of life of the natives and diminishing the efficacy of propaganda.

(4) An impoverishment of the rural communities who, because of their small income, looked for other profitable labour as workers in towns or plantations.

In short, at that time, a decrease in production began just when needs were increasing.

AIMS AND AGRONOMIC PRINCIPLES OF THE SETTLEMENTS

The aims of the settlements are: (1) conservation of soil fertility, (2) improvement of productivity by rational farming, (3) stabilization of the rural population by increasing their income, (4) cessation of nomadic agriculture (shifting cultivation).

At first sight the ' Bantu system ', based on polyculture, a short period under crops and a long-term fallow, shocks the agronomist. The inter-planting of crops often leads to a decrease in yield, if not of all, at least of the most profitable crops. Some, such as cotton and groundnuts, are not suited to the practice. The long-term bush fallow reduces considerably the profit that can be obtained from the soil, and entails hard work for each clearing. Moreover, it prevents any possibility of mechanized farming.

It seemed logical, with the object of improving yields, to modify completely the customary methods of cropping. At several research stations, experiments inspired by European techniques were undertaken, *e.g.* cutting and clearing of all the stumps, deep ploughing, short-term grass or leguminous fallow, organic manures (compost or mulch) or artificial fertilizers.

Some of these methods, such as deep ploughing with leguminous fallow, almost always had deplorable results. Grass fallow has given contradictory results, often unfavourable in the absence of mineral fertilizers. On the other hand, although it is true that heavy mulching or composting permits the maintenance or improvement of a very high productivity, these practices are not feasible in the present state of native agriculture.

As the prevalence of tse-tse fly in the forest area prevents cattle-raising, the native farmer has neither dung, draught animals, nor means of transport at his disposal; ploughing and heavy spreading of organic material is thus impracticable. Moreover, most of his crop products are bulky in relation

to their small value and can only be transported to the towns or exported at high cost. On account of this last fact, the application of imported artificial fertilizers is often not paying.

After the failure of these techniques, the Research Centre of INÉAC at Yangambi reconsidered the study of the 'Bantu system' which alone seemed to safeguard and to regenerate the soils.

While studying means for improving this native method, it was soon observed that the length and shape of the blocks cleared in the forest were of paramount importance, owing to the obvious influence of the forest border: if the blocks cleared are too small, it is prejudicial to the crops, if too large, the regenerating fallow suffers. Experiments were carried out particularly to study the edge effect of the forest. The conclusions may be summarized as follows:

(1) The cleared blocks must have their long axis east–west, so as to provide maximum light for the crops. The length of the strips is not important, beyond a minimum of 200–300 metres, but the optimal breadth is about 100 metres.

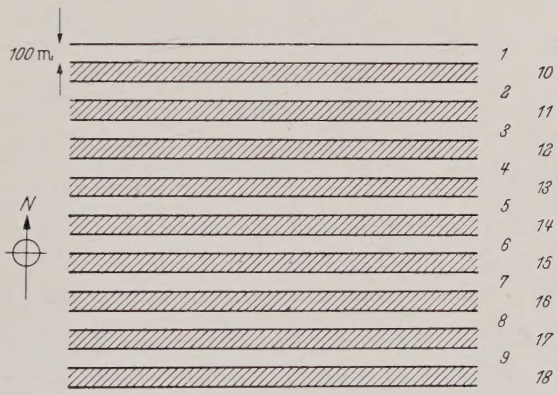

Figure 1

(2) In these conditions, loss of yield due to proximity of the south and north border amounts to 10 per cent for clearings in heavy forest but falls to 3 per cent when forest fallow is cleared. In the case of cotton culture, the edge effect may be a little more important. In drought periods, these losses may be compensated by the protective action of the border on the field.

(3) The proximity of the forest at the north and south edges promotes rapid growth of forest fallow on the abandoned field (by maintenance in the clearing of a forest micro-climate and by the presence of mother-trees); this is the reason why the cultivated strip should not be broader than 100 metres.

(4) To preserve these advantages, it is necessary to organize land tenure according to a system of alternating strips of crops and forest. The clearing of the forest blocks begins when the cultivated blocks have lain fallow for a reasonably long period.

In *Figure 1*, the strips are numbered according to the scheme of clearing. Supposing a short rotation of three years is adopted, it will be seen that

strip *10* will be cleared when strip *1* will be in its seventh year of fallow and strip *2* in its sixth year. These alternating strips also provide a protection against plant diseases and the spread of bush fires which are always possible in young fallows where grasses may be abundant.

It may be objected that the heavy forest species do not take any part in the fallow regeneration. Yet it is to be noted that the species of a ten year old fallow are sufficiently developed to play an active role in the new growth of the abandoned fields.

METHODS OF SETTLEMENT

Settlement in a forest area thus consists of establishing the farmers on demarcated blocks, which they will cultivate on the corridor system, with a given rotation and area to be farmed yearly with a fixed and sufficiently long term of bush fallow.

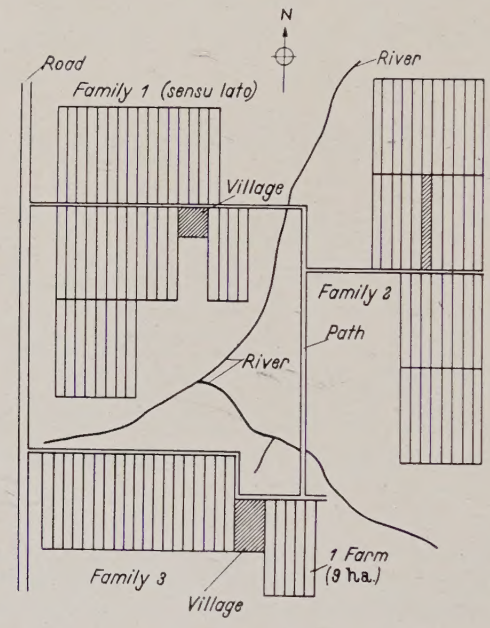

Figure 2

The method of settling and the programme followed vary according to the different crops, the nature and distribution of good soils, local customs and the degree of education of the native. However, the various settlements all agree in the fact that the cultivator remains on the land of his clan.

Individual property is unknown to the native farmer. The land belongs generally to the clan (group of individuals descending from the same ancestor or group of families *sensu lato*), each individual having a right of usufruct in the field he cultivates, the crops being his personal property. When the land is laid fallow, it again becomes communal patrimony.

Settlements may be established according to one of the two following ways: (1) Method of the Babua settlement; (2) Method of the Turumbu settlement.

1. Method of the Babua Settlement (so-called 'individual method'). Area of Bambesa-Uele

A general survey of the land to be allotted is made under the direction of a European agronomist. This is to find out the extent of arable soils. At the same time, the Civil Administration holds a political enquiry concerning the genealogies and territories of the clans, the land of which each family (*sensu lato*) may dispose, and also the number of individuals to be provided with a farm.

From these enquiries and surveys, blocks of farms are marked on the land in such a way that all the individuals of one family (*sensu lato*) can be settled on the land they used to cultivate normally (*Figure 2*). In any block, each

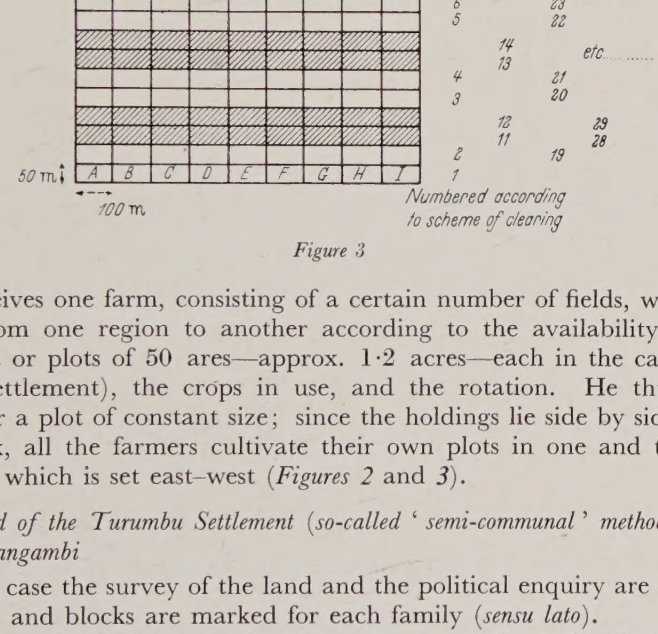

Figure 3

man receives one farm, consisting of a certain number of fields, whose size varies from one region to another according to the availability of land (18 fields or plots of 50 ares—approx. 1·2 acres—each in the case of the Babua settlement), the crops in use, and the rotation. He thus clears each year a plot of constant size; since the holdings lie side by side within the block, all the farmers cultivate their own plots in one and the same corridor, which is set east–west (*Figures 2* and *3*).

2. Method of the Turumbu Settlement (so-called 'semi-communal' method). Area of Yangambi

In this case the survey of the land and the political enquiry are operated as above, and blocks are marked for each family (*sensu lato*).

Each year the corridor to cultivate, set east–west, is marked in the block in which, at the time of allotment, each man receives a plot proportional to the working capacity of his family (*sensu stricto*) (*Figure 4*).

The difference between the two methods lies in the fact that in the individual method (Babua), each family holding forms from the beginning, an individual, demarcated strip of regular shape, identical with the others, which runs north–south across all the corridors, while in the semi-communal method (Turumbu) each family receives annually an individual plot in

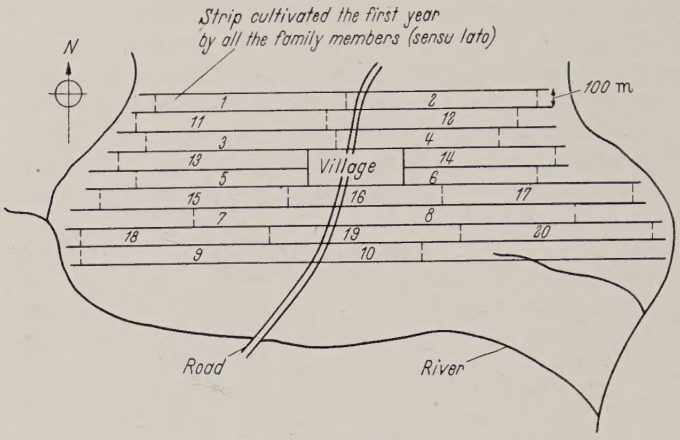

Figure 4

the corridors which are marked from the beginning; the size and disposition of each family plot may thus vary from year to year and according to family strength. However in both cases the ownership of land remains collective. In the Babua method each man receives from the tribal authorities, when settling, not the ownership but the usufruct of the farm until he dies or abandons it. The farm then returns to the common patrimony and is again allotted as a whole by these authorities to another member of the family (*sensu lato*), the latter being not necessarily a true heir of the previous holder. As for the Turumbu method, the annual field of each farmer returns, *when the rotation is ended*, to the collective property.

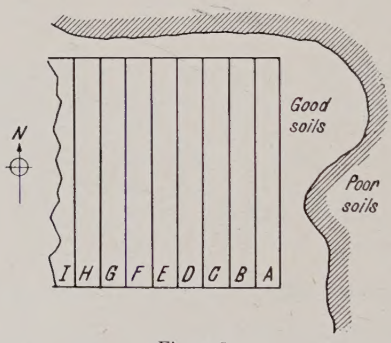

Figure 5

These two methods present the following advantages and disadvantages:

1. Individual type (Babua)
Disadvantages:

(*a*) Rigidity of shape, for the blocks must be square or rectangular to set the farms north–south and the corridors east–west, and therefore provide a less rational use of the available arable soils (*Figure 5*). This argument is only of value in overpopulated areas where good soils are scarce. The introduction of perennial crops mitigates this disadvantage.

(*b*) Initial settlement is more expensive; the marking of all the farms and blocks must be finished before allotment to the farmers.

(*c*) The field cleared annually by each farmer is of invariable size, which does not permit adaptation to the working capacity of the family (*sensu stricto*). This, as we shall see below, is greatly lessened by a well-chosen rotation and the possibility of co-farmers.

(*d*) Interruption of cultivation on one farm in the block (by death or abandonment), causes a stop in the corridor, thus diminishing the advantages of the corridor system.

Advantages:

(*a*) Method better adapted to tribes with a marked individualist mentality.

(*b*) The farmer, being certain of the permanent possession of the farm's produce, will be induced to preserve and improve his land by good cultural practices. He will remain with it, and not be so ready to leave the rural community.

(*c*) It is a stage towards the recognition of individual ownership of land; this has been the subject of much discussion both from the social and economic point of view.

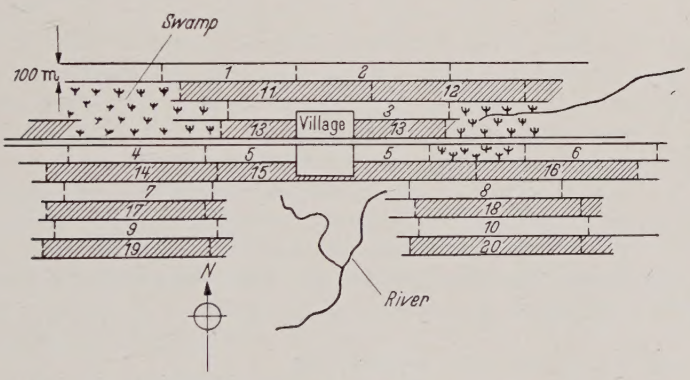

Figure 6

2. *Semi-communal type* (*Turumbu*)

Disadvantages:

(*a*) Necessity to choose and mark the corridors, and allot each man his field, every year.

(*b*) The farmer will not respect land he is not sure of cultivating again. He will be less certain to settle down in the rural community, as his departure will only involve abandonment of a way of life, not of an estate to which he is attached.

Advantages:

(*a*) Better use of the arable soils and easier settlement in over-populated areas; the annual corridor may be moved east–west as the arable soil demands (*Figure 6*).

(*b*) Less expense in the initial settlement; this is a very short-term advantage, for the choice and marking the corridors must be repeated every year.

(*c*) The area cultivated by one man can be changed at will every year.

(*d*) Easy modification of land management in order to apply improved methods such as mechanization or fertilizer application, which, for obvious economic reasons, require a greater area per tenant.

Both methods preserve the advantage of grouping the small individual fields in large clearings, which facilitates agronomic propaganda, plant sanitation, and control of crop pests. Both are in use, the choice depending on the more or less marked individualism of the native and on the available land.

FALLOW AND ROTATIONS

When one considers the establishment of a settlement, especially one of the individual type, it is indispensable to decide beforehand, and with enough precision, the rotation to use and the length of fallow needed to restore the initial fertility of the soil. The size of the blocks to be marked depends on the number of annual fields foreseen for each farm.

The Fallow—Agronomic research in the Belgian Congo is relatively recent; the beginning of the systematic and rational study of the 'Bantu system' dates only from about 15 years ago. The experiments are not of sufficient duration to be precise about the length of fallow that will enable the maintenance of yields during a great number of crop–fallow cycles. In most of the settlements in the forest area, both individual and semi-communal, a term of 15 years was adopted. This was based on observations and preliminary studies some of which are still in progress.

Though this term seems to be quite adequate in the central Congo basin, where the fallow rapidly becomes a nearly pure *Musanga** formation, which can be cleared and cultivated again with success, it is observed that in the tropical rain forests situated on the border of the depression, the dynamism of regrowth is distinctly less intense.

A term of 15 years is then a minimum, which would be dangerous to reduce until the experiments are concluded.

The Rotations—The rotation to be used in the various regions can largely contribute to the protection of the soil and a better use of its reserves. It will depend of course on the observations made in each case and on the agronomic conclusions peculiar to the area.

From numerous experiments made in the forest region, the following rules should be observed:

(1) Two weeded crops with a short vegetative cycle may be grown in the same year on the same field: the first sown at the beginning of the short rainy season and harvested during the short dry season (season A), the second beginning with the long rainy season and harvested during the long dry season (season B).

(2) Annual weeded crops (maize, groundnuts, soya, cotton, *etc*), being very sensitive to weed competition when young and therefore receiving several early weedings, expose the soil to sun and rain. They are chiefly responsible for its rapid degradation.

**Musanga cecropioides* R.Br. (syn. *M. smithii*). English, 'umbrella tree'; French, '*parasolier*'—Ed.

Four consecutive seasons (two years) of these crops form a maximum which may not be exceeded if the forest regeneration is to be rapid enough to prevent invasion by grasses. This regeneration is mainly dependent upon the young shoots of the many stumps remaining in the field after clearing; if cut too often while weeding, these will not produce further shoots.

(3) Perennial crops such as bananas, cassava, *etc*, do not require much care, protect the soil better, and do not have much influence on its residual fertility.

(4) Except for some graminaceous plants (rice, *Coix*), annual crops planted immediately after clearing heavy forest do not yield well.

(5) Perennial crops (bananas and cassava) are well suited to these conditions and are therefore an excellent preliminary for annual crops. For two or three years during which they occupy the field, they loosen the soil with their roots, favour its aeration, and promote the accumulation of water reserves (especially in heavy clay soils); the *p*H, acid in forest soils, rises considerably; the enormous mass of organic residues of the fallow decomposes and mineralizes in part.

At Bambesa, evidence has been established that, after bananas, the base exchange capacity and the pH of the soil were definitely higher than after clearing.

(6) When clearing young fallows (12 to 15 years), perennial crops are no longer a necessity. In this case the yield of annual crops is quite satisfactory, even when they come immediately after clearing. Nevertheless it will be convenient to grow crops which are the main income of the cultivator (cotton, groundnuts) during the second year of the rotation, for it is at this stage that the highest yields are obtained.

(7) The mere fact of cutting a bush fallow one year before its cultivation in annual crops will cause great improvement in yields.

From these rules and many other local experiments, several rotations have been used in the settlements in the forest area, of which the following may be given as examples.

A. Babua Settlements (individual type)

Bush fallow of 15 years. Annual field of 50 ares (approx. 1·2 acres). After clearing and burning.

1st year:	Season A:	Rice—10 ares. Maize with beans and pumpkins —40 ares.
	Season B:	Cotton—40 ares.
2nd year:	Season A:	Groundnuts—50 ares.
	Season B:	Cotton—50 ares. Bananas with cassava planted between cotton two months after sowing.
3rd year:	Bananas with cassava, not weeded. Regrowth of the fallow.	
4th year:	Harvest of bananas and cassava.	
5th year:	End of harvest of bananas in the fallow.	
6th to 17th year:	Bush fallow.	

Altogether 17 fields for the different crops of the rotation, plus one for the garden, a small orchard, and eventually the farmer's house if he so wishes; *i.e.* 9 hectares (22·2 acres) for one farmer.

B. Settlements in Buta and Paulis Area (individual type)

Old fallows or heavy forest. Annual field of 40 ares. Heavy clay.

1st year: Season A: Bananas with rice.
Season B: Bananas with cassava after rice harvest.
2nd year: Bananas with cassava. Beginning of harvest during Season B.
3rd year: Bananas with cassava. Harvest.
4th year: Season A: Maize with pumpkins and beans.
Season B: Cotton.
5th year: Season A: Groundnuts.
Season B: Cotton.
6th to 19th year: Bush fallow.

Altogether 19 fields for the crops of the rotation, plus one for garden, orchard and house; *i.e.* 8 hectares (19·8 acres) for one farmer.

C. Turumbu Settlements (semi-communal type)

Heavy forest. Poor sandy soils.

1st year: Season A: Maize.
Season B: Rice with cassava and bananas.
2nd year: Cassava with bananas.
3rd year: Cassava with bananas—harvest.
4th year: Maize, beans, and groundnuts separately.
5th to 20th year: Bush fallow.

Altogether 20 strips to provide for each family; their length varies according to the number of individuals to be provided for.

All these rotations are followed by long-term fallows. Amongst them several will have to be modified according to experiments and observations not yet concluded.

The disadvantage has been stressed above, in the individual type, of clearing an annual field of fixed size not adapted to the working capacity of the family (*sensu stricto*). This situation can be alleviated in the Babua system as follows. The entire Babua rotation supposes the annual cultivation of 10 ares of rice, 40 ares of maize, beans and pumpkins, 50 ares of groundnuts, 90 ares of cotton, and 50 ares of cassava with bananas. The whole of these crops, plus the clearing work and the conveyance of the products to market and their sale, require 290 to 300 working days for an adult. Moreover, the farmer harvests semi-wild oil palms, hunts, fishes, and does chores about his house.

Though the total labour requirement of the farm represents a possible maximum for the farmer helped by the members of his family, it is certainly excessive for the bachelor. Though the community requires that he clears his annual field completely, to preserve the advantages of the corridor system, nevertheless he has latitude to limit the area planted to crops according to his needs. He will maintain the export crops (cotton and groundnuts) of the second year, which are the most productive and the basis of his income, but reduce the importance of his food crops (maize, pumpkins, beans, rice, cassava) as well as the cotton of the first year which is less productive. Another possibility, also in use, is the association of two bachelors in working the same holding.

SETTLEMENTS IN SAVANNAH

The systematization of agriculture has not been limited to the forest area; settlements were also tried in the savannah region. Their aims are the same as outlined above: better studied rotations and cultural practices, affording a rational farming of the soil, so as to assure maximum productivity and control of the length of fallow.

As in forest, the corridor system is adopted, but successive corridors for cultivation are either contiguous or alternate according to topography. This system also affords protection from soil erosion, which is one of the main problems of soil conservation in undulating savannah country. Settlements may be organized according to the individual or semi-communal type for the reasons given above.

PERENNIAL CROPS IN THE SETTLEMENTS

The income of the African farmer is at present based, in most cases, on too small a number of industrial crops (groundnuts and cotton). The other food crops comprised in the rotation provide bulky produce which is not easily exportable; they are only used to feed the farmers and sold on a limited local market.

The introduction in the settlements of perennial crops (coffee, oil palm, rubber, cocoa) has the advantage, not only of giving variety and stability to the income but of increasing it to a fair extent, while cultivating smaller areas than those necessary for the annual crops. In settlements of the individual type, it lessens the disadvantage of the rigidity of shape. Good soils which are badly distributed, or too small in area to establish a block of farms of many hectares, can very often be used for the cultivation of several hectares of perennial crops, which can be divided between neighbouring farmers.

Finally, in the case of scarcity of land, the income of the farmer can be based on the establishment of plantations demanding the working of a smaller area; a much reduced annual field can assure the production of food needed for the subsistence of the people. In the particular case of Uele, it has been calculated that a farm with income based on the production of coffee and palm oil and secondarily on cotton, gives the same profit to the farmer as that of a Babua farm producing primarily groundnuts and cotton and secondarily coffee and palm oil.

The first would need 18 fields of 20 ares each for the annual crops, 20 ares of coffee and 35 ares of oil palm, altogether 4·15 hectares; the second 18 fields of 50 ares. 10 ares of coffee and 20 ares of oil palm, altogether 9·3 hectares.

Programmes of perennial plantations are envisaged and have even begun in several settlements in the forest area.

CONCLUSION

The settlements as they exist at present do not consist in the introduction of intensive methods of cultivation.

They are the rationalization of the ancient system of shifting cultivation which, formerly existing in a disorderly way, risked producing a total destruction of the land capital. This simple method can already show a

notable increase in productivity, for it avoids a ruinous over-exploitation, uses tried rotations and permits the agents of government to establish in the native agricultural society more fruitful supervision and propaganda. More intensive culture methods might be adopted later. The introduction of short-term grass fallow (eventually grazed), the use of artificial fertilizers and of green manure, and the mechanization of several cultural operations is planned; in all these fields studies have already been initiated and will progressively be completed at the research stations of INÉAC.

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Ratoon Stunting Disease of Sugar Cane

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Despite the fact that ratoon stunting disease has no external symptoms by which it may be definitely diagnosed, Queensland cane farmers are very much aware of its presence. In all the cane-growing areas, major yield decreases in almost all the currently popular varieties have been attributed to this disease, and experiments carried out by the Bureau of Sugar Experiment Stations have regularly confirmed this view. However, efficient control measures have been developed by the Bureau and are now being applied on a large scale with a view to the eradication of the disease.

Ten years ago in the important Mackay district in Central Queensland many ratoon crops of the variety Q.28 failed to develop after an unusually dry spring and early summer. Some fields or even parts of fields, instead of showing several months growth, appeared to have been just harvested, while in the others growth was normal. The differences were so marked that it was suspected that a mutation had occurred in the variety. Experimental work by the Bureau led to the conclusion that this slowness in ratooning, with subsequent poor yield or even total failure, was due to a disease-producing agent and the malady was eventually designated ' ratoon stunting disease '. It was later shown that other varieties were similarly diseased, that infection was also present in other areas and that the yield of plant cane as well as that of the ratoons was substantially reduced.

ECONOMIC IMPORTANCE AND SYMPTOMS OF INFECTION

In plant cane, infection does not significantly lower the germination of setts nor does it appear to have a marked effect on the number of canes produced in the mature stool or on the purity of the juice. Losses are mainly due to a reduction in the rate of growth, *i.e.* a depressing effect on the length and possibly the diameter of the canes produced. This stunting is aggravated under dry conditions, when diseased plants show drought reactions earlier and more markedly than non-infected cane. The result of this depressed vigour in plant canes is the loss of up to 10 tons of cane per acre, *i.e.* over a ton of sugar. *Table 1* summarizes the plant crop yields of five trials laid down by the Bureau of Sugar Experiment Stations in the Mackay district.

In ratoon crops of Q.28 the symptoms are aggravated. Infected ratoons grow very slowly under conditions favourable to the disease, the shoots are smaller and fewer in number than in comparable healthy stools and this difference is maintained until maturity when the number, average length and diameter of the stalks may all be inferior. As with the plant crop, infection renders the ratoons more susceptible to drought and in extreme cases death of the stools may result.

Table 1. Effect of ratoon stunting disease on plant crop of variety Q.28

Trial No.	Yield (tons cane/acre)		Loss
	Healthy	Diseased	
1	28·6	17·9	10·7
2	36·0	27·7	8·3
3	30·2	23·9	6·3
4	40·1	33·1	7·0
5	37·3	33·0	4·3

Table 2 shows the effect of the disease on the yield of the ratoon crop in the variety Q.28. These results are from the same trials as *Table 1.*

A more insidious effect of the disease is the discarding of potentially good varieties due to its increasing incidence in them. For example, in the variety Q.28 mentioned above which was once the leading variety in the central Queensland area and at its peak yielded 800,000 tons of cane per annum, increasing infection caused such considerable losses that this variety had to be supplanted by others. However, following treatment it has been shown that this variety is still capable of its original cropping capacity. It is possible that a similar explanation could apply to the discontinuing of other varieties in other parts of the world.

Table 2. Effect of ratoon stunting disease on first ratoon of variety Q.28

Trial No.	Yield (tons cane/acre)		Loss
	Healthy	Diseased	
1	27·6	9·6	18·0
2	20·5	7·5	13·0
3	17·0	10·0	7·0
4	29·6	11·4	18·2
5	30·3	10·0	20·3

Apart from stunting, which may, of course, be produced by a variety of factors other than ratoon stunting disease, there are no external symptoms indicating infection. Internally, the presence of the disease is indicated by yellow to red discoloration of vascular bundles at the base of the nodes. A few or many bundles may be so affected and can be seen with the unaided eye on cutting longitudinally through the node. Such discoloration is not entirely diagnostic as it also occurs in cane which has been subjected to insect attack or infection with certain other diseases. Microscopically, the cause of the vascular discoloration is seen to be occlusion of the vessels with gum and the staining of their walls and surrounding tissues, but neither microscopic nor cultural techniques have yielded fungi or bacteria. The causal agent is almost certainly a virus although conclusive proof is still absent, as with most other suspected virus diseases of sugar cane.

TRANSMISSION

Ratoon stunting disease is transmitted mechanically. There are no known insect vectors and no evidence that the agent can survive in the soil

or occur naturally on alternate hosts. The juice from diseased stems is only infective for a short period at normal temperatures but retains its infectivity up to dilutions of 1:10,000. Successful inoculations may be made by the injection of infective juice into growing stems, by dipping the cut ends of planting material in inoculum, by pressure inoculation into setts, or by cutting setts with a knife dipped in inoculum. Under commercial conditions, transmission occurs either by propagating infected stock or by preparing planting material with contaminated knives or machines, but secondary infection may occur during harvesting when cutters, alternately reaping diseased and healthy material, transmit the disease with knife blades.

Figure 1. Ratoon stunting disease in ratoons of Q.28. The central row has been infected by the cutter–planter as the setts were planted

CONTROL MEASURES

The most obvious and effective precaution is the use of disease-free planting material. Knives or machines used in its preparation can be sterilized before use by means of disinfectants or flaming. If healthy setts are planted in fields in which no diseased volunteers from previous crops arise and if harvesting knives are sterilized prior to use in the field, then complete control is assured.

The only real difficulty lies in the choice of propagating material which is known to be disease-free. In the absence of such stocks, it is not sufficient to choose setts from any field which appears healthy unless its history is well known. In some fields the disease may be masked due to the varieties grown being tolerant to infection or to the abundant availability of water. This is especially true of plant cane in which stunting is much less obvious and the possibility of recent infection must be considered. The best choice,

until specific crops or estates are known to be disease-free or until healthy nurseries are established, is ratoon cane taken from a dry, non-irrigated region which has no recently introduced planting material from infected areas and where ratoons of a susceptible variety have proved consistently high-yielding.

Heat-treatment

The Queensland Bureau of Sugar Experiment Stations has shown that the pathogen, like that causing chlorotic streak disease, may be inhibited in planting material by subjecting it to heat treatment. This allows disease-free nurseries to be established from infected or suspect stock. In the case of ratoon stunting disease the thermal death point of the causal agent is relatively high; the treatment necessary approaches the thermal death point of the cane, so that if reasonable germination is to be obtained, the equipment must be capable of precise control and the uniform treatment of every individual sett.

From the range of effective treatments possible the one most commonly used consists of two hours immersion in water at 50°C. Tolerance of hot water treatments varies considerably in different varieties and, even when the more heat-tolerant setts from hardened mature cane are used, germination in some varieties is poor or even completely suppressed. Since heat treatment inevitably leads to the death of some cells of the planting material it increases the chance of invasion by soil organisms after planting. This is overcome by the use of suitable fungicides. Dipping in 'Aretan' at a strength of 1 lb./20 gal. of water has been found satisfactory; alternatively the fungicide may be included in the hot water bath, when a concentration of 1 lb./100 gal. of water is adequate provided the solution is changed at intervals of not more than five days.

PRESENT POSITION IN QUEENSLAND

It was early seen that, with the availability of a method of eliminating infection in setts and with the transmission methods known, it was theoretically possible to reduce the incidence of ratoon stunting disease to negligible proportions. Demonstration plots of infected and healthy cane were established and these have offered growers convincing proof that control of the disease was desirable. The policy has been to build up guaranteed clean stocks of all commercial varieties in each area and hot water treatment plants operated under the supervision of officers of the Cane Pest and Disease Control Board were established at several mills. In addition, the boards assisted in the supervision of planting the treated material and inspected the crops grown from it. In two of Queensland's twenty control board areas the entire 1955 plantings have been made from disease-free stock and in these areas legislation now makes it compulsory for all growers to plant such cane. It is expected that during the coming seasons planting from disease-free stocks will be mandatory throughout the whole of Queensland. When this occurs, all that is necessary to ensure complete success of the scheme is the prevention of cross-contamination from standing diseased ratoons. Regular inspection will determine whether it is necessary for

boards to continue supplying healthy material or whether growers themselves are easily able to maintain clean stocks.

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The Application of Commercial Methods of Vegetable Growing in the Eastern Region of Nigeria

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In the rural areas of the Eastern Region of Nigeria carbohydrate-rich foods such as yam, cassava and cocoyam predominate in the diet of the great mass of the population[1]. Green vegetables are, however, recognized as an important and necessary adjunct to the more bulky foods, and many indigenous trees and shrubs furnish edible shoots which have traditionally been gathered for culinary purposes. Among types of vegetables familiar to the European, the tomato is of outstanding importance and was probably introduced by the Portuguese in the late 15th century. A bitter type of garden egg, *Solanum melongena** and the chilli pepper are also widely grown for flavouring purposes.

During the last ten years the Eastern Region of Nigeria has undergone profound social and economic changes which have caused an increased movement of the population from rural to urban areas. Coupled with this redistribution, there has been an overall increase in the population. These trends have not been accompanied by corresponding increases in vegetable production in the urban areas, so that town dwellers are finding it increasingly difficult to buy the herbs and vegetables to which they were originally accustomed in their villages.

Large scale production of vegetables has, in the past, been concentrated around Kano, one of the largest towns in the Northern Region, and around hill stations such as Jos and Bamenda. Although Jos and Kano are served by main railway lines, they are so far from the main centres of consumption in the Eastern Region that vegetables undergo considerable deterioration during transit, while in the case of Bamenda, which is situated in the British Cameroons, a haul of more than 300 miles over bad and often impassable roads has been a continual obstacle to the establishment of a commercially stable vegetable growing industry.

During the last war vegetable production rose considerably with the increased demands from troops stationed in Nigeria; small growers who entered the business for quick gain were able to supply these demands, but the majority closed their gardens when the war ended and large profits could no longer be obtained.

The Department of Agriculture has always maintained vegetable plots on its experimental farms, where imported seed of the more popular types of vegetable has usually been available for distribution at cost price. Small-scale seed production was a particular feature of the work at Bamenda,

* Throughout this paper the names used are those given by H. F. Macmillan, 'Tropical Planting and Gardening', and J. M. Dalziel, 'The Useful Plants of West Tropical Africa'.

where the experimental farm is situated at more than 5,000 feet above sea level. In most of the smaller stations with a permanent European community, small vegetable gardens were established and the results varied with the knowledge and interest of the supervisor, usually the wife of a Government official. By their nature these small gardens could not produce reliable information on the performance of different varieties or on the nutrient requirements of temperate species growing under tropical conditions.

Realizing the need for more accurate information on this important facet of agricultural development, the Department of Agriculture, Eastern Region, decided to establish a Pilot Urban Market Garden Scheme at Enugu, the regional seat of government, and a site was acquired early in 1950.

THE DEVELOPMENT OF THE MARKET GARDEN AT ENUGU

The development of the Enugu market garden was dependent on a readily available source of organic matter to sustain continuous cropping. Owing to the high incidence of trypanosomiasis in the area, large herds of cattle cannot be maintained by the local farmers, and organic manures of animal origin are therefore not available. This factor caused the Department of Agriculture, to begin, in 1949, a scheme to assist in the development of factories for the manufacture of compost from night-soil residues and market waste in several of the larger townships in the Eastern Region, including Enugu. The manufacturing method was that employed at Kano[2] in the Northern Region, where permanent chambers were used for the turning of the material. At the Enugu factory production has risen from 80 tons in 1949 to over 1,000 tons in 1954, an increase which can to some extent be attributed to the results obtained at the market garden, where Nigerians have had the opportunity of seeing the impressive yield increases which have followed the application of this type of organic manure. It may be mentioned in passing that at first great antipathy was shown towards the use of an organic manure derived from night-soil, but this local prejudice is slowly disappearing and night-soil compost is now being widely used by progressive growers.

Since little information was available on the difficulties to be encountered in vegetable growing, it was first necessary to establish a general policy for development. The first requirement was to ascertain which types of vegetable could be grown commercially under the conditions prevailing at Enugu. When this information was available, the provision of training facilities for Nigerians wishing to start market gardens of their own would become an essential part of the scheme. From such Nigerian owned gardens there would be a continuous demand for supplies of seed of the varieties found to be most suitable. It quickly became apparent that difficulties would be encountered if reliance was wholly placed on supplies of seed from external sources and for this reason the production of acclimatized seed formed an essential part of the work of the pilot scheme.

A nine acre plot situated in Enugu township was acquired in 1950. The area chosen had previously been cropped to exhaustion with cassava and the soil was markedly infertile. Topographically the site could be divided into three parts: $3\frac{1}{2}$ acres at the northern edge were relatively

flat, while the remainder, which was on sloping land, could be further sub-divided into an area of $4\frac{1}{2}$ acres where the slope varied from 1:10 to 1:5, and one acre along the southern edge where the slope became progressively steeper until the land fell away precipitously to the bed of a perennial stream.

Although no soil survey has been carried out in the area, the soils of the flat portion at the northern end of the site, where vegetable growing is now concentrated, may be broadly described as free-draining silty sands derived from colluvial material washed down from the surrounding hillsides. On the sloping land, where considerable erosion has occurred, it would appear that an underlying cap of a concretionary ironstone has been exposed, and this area is being used for a demonstration orchard of citrus and tropical fruits. The area immediately adjoining the stream has been terraced, the retaining walls being built with the ironstone material mined from the outcrop mentioned above; this land is now being used for vegetable crops.

The climate at Enugu is generally typical of the northern edge of the rain forest zone. The rainy season extends from mid-March until the end of October, and at the beginning and end of this period severe thunderstorms are often experienced and sometimes cause considerable damage. About mid-August a 'small dry' of approximately ten days duration is usually experienced. In the middle of the dry season, either before or after Christmas, occasional light showers occur, but these are rarely of sufficient duration or intensity to be of horticultural significance. Mean annual rainfall over the last ten years has been about 72 in. per year.

Methods used in the development of the site

Only a few privately-owned gardens existed in the region at the time the scheme was started, and in these it was the common practice to grow vegetables on raised beds which were invariably constructed at right angles to the contour, since the local growers considered it essential to facilitate the rapid dispersal of excessive surface water. This practice led to severe gully erosion, loss of valuable top soil and a progressive decline in soil fertility. The value of compost was not appreciated, although a few Nigerian gardeners dug in dried grass when making the beds.

Soil conservation measures formed an integral part of the development of the Enugu site, care being taken to see that all the raised beds were laid out on the contour. It was decided to develop the area in individual sections of approximately $\frac{1}{3}$ acre each. Each section could then be treated as an individual unit in which all types of vegetables could be grown. A further advantage was that units of this size afforded permanent employment to two labourers, who, it was hoped, would in the course of time develop market gardens of their own. It was not the intention that this should be the only form of training, and the instruction methods evolved are given in a subsequent part of this paper.

Sections to be used in the accumulation of yield records and other technical information consisted of beds each 100 square feet in area. These were laid out in a staggered arrangement so that the cross paths would not promote gully erosion. The use of an 'isolation' strip between the sections, eight feet wide and grassed with *Axonopus compressus* virtually eliminated loss of

soil from run-off. Mention might here be made that larger beds which were constructed later proved less satisfactory, inadequate drainage at the centre of the bed having an adverse effect on the yields. All the beds in the market garden are numbered within the sections, the latter being 'lettered' from *A* onwards. The necessity for this is explained on page 23 where records are discussed. In the construction of these raised beds, of which approximately 60 were contained in each section, hand tools were used throughout. The entire market garden, in fact, was developed without the use of machinery. In this way it was hoped to ensure that Nigerians would realize that a market garden could be developed by a person of limited capital.

Double digging of the whole area, using pickaxes to break up the compacted layers, preceded the construction of the raised beds and the soil was 'worked' to a depth of fifteen inches.

In the labour force employed, educational standards ranged from illiterates to some who had attained Class IV secondary school standard. In this way it was hoped to show that whilst a measure of education would assist a man to absorb the more technical details of the work, it was possible to teach a man with no education how to grow good vegetables. Some of the original labour force who had only received primary education have, in fact, been found appointments elsewhere, where they are in charge of small market gardens.

Soil fertility

The maintenance—and later improvement—of the level of soil fertility in the market garden was based on the use of night-soil compost. In the period under review it has not been possible to establish from experiments the maximum economic dressing, but from 1950 onwards the organic matter content of the soil has increased considerably, and the colour has changed from a pale greyish-brown to a rich medium brown.

A dressing of three head-pans of night-soil compost per bed of 100 square feet has been applied to all plantings, with the exception of carrots. This is a convenient method of measurement, and three head-pans contain 120 lb. compost at average moisture content. Three head-pans of compost per bed are therefore equivalent to 23·3 tons of compost per acre. As the cropping programme permits three crops to be obtained from most beds in one year, the majority of the beds receive compost at the rate of some 70 tons per acre, in one year.

The cost of night-soil compost, which was 12*s* 6*d* per ton in 1950, rose to £1 a ton in 1952 largely due to increases in labour rates. Increased production brought about by the use of more economic methods has recently caused consideration to be given to price reduction. The price increase mentioned above did not affect local growers, who have been receiving supplies at the lower price.

The acid nature of the soil necessitates the application of lime, and a low grade product, containing 40 per cent CaO, is available locally. Two general dressings have been given, in 1950 and 1952 and in each case the lime was applied ten days before the compost at the rate of 1 lb. per bed, equivalent to 325 lb. per acre.

In 1950 no information was available on the nutrient requirements of

vegetables growing under the conditions existing at Enugu. For this reason, all work on fertilizer dressings has so far been of an empirical nature and has been confined to the basic elements nitrogen, phosphorus and potassium. The dressings of nitrogen, phosphorus, and potassium applied to the various vegetables grown at Enugu are summarized in *Table 1.* It must be stressed that these dressings are provisional, being based on experience which has accumulated among vegetable growers in England, since, as previously stated, little or nothing is known of the manurial programmes necessary for the cultivation of vegetables in Eastern Nigeria. Already mineral disorders are appearing in certain crops (sweet corn, for example, develops potassium deficiency on the market garden at Enugu) and the dressings set out will be modified as more evidence becomes available. Possible needs for trace element supplements will be investigated when the basic fertilizer requirements have been ascertained. It is hoped to perform statistically planned fertilizer experiments with all types and varieties of vegetables which prove tolerant to the conditions prevailing at Enugu, but so far staff shortages have made this impossible.

Table 1. Fertilizer dressings used for vegetables at Enugu

Crops	*Fertilizer applied (lb./bed)*		
	Ammonium sulphate	*Superphosphate*	*Muriate of potash*
Beans: cowpeas	—	0·5	0·5
Lettuce: beetroot: carrot: endive	—	1·0	—
Tomato: cucumber: garden egg: pepper	0·1	0·6	0·3
Cabbage: cauliflower: turnip: kale	1·0	—	—
Pineapple: sweet corn	1·0	—	—

Crop rotation

With continuous cropping forming an essential part of the work, it was necessary to establish a suitable crop rotation. This rotation would to some extent be a compromise as demands for the various vegetables would not be equal. The four year rotation given below has so far proved satisfactory, but may have to be changed in the light of further experience. As each line of beds in a section is used for a group of crops for a whole year, it is possible to rotate the crops in that line during the year, so that a ' bottom ' crop follows a ' top ' crop, *e.g.* lettuce followed by carrots. The rotation at present adopted is:

1st year: Beans, cowpeas, onions, leeks and celery.
2nd year: Carrot, lettuce, beetroot and endive.
3rd year: Tomato, garden egg, sweet pepper, chilli and cucumber.
4th year: Cabbage, cauliflower, broccoli, kale and turnip.

A fifth line of beds is maintained in each section for slower maturing crops such as pineapple and asparagus, which would, if included in the four year rotation, cause problems due to their remaining in the beds for more than

one year. In this fifth line the rotation used is: pineapple, sweet corn, Chinese yam and okra. Asparagus is grown in permanent beds.

THE PERFORMANCE OF VEGETABLE CROPS AT ENUGU

As the accumulation of information on the various types and varieties of vegetables grown at Enugu was of paramount importance, a system of recording was instituted when the first seeds were sown. In this system four permanent record books are used:

(*a*) *The Crop and Yield Book.* This contains the records of each crop from sowing to harvest.

(*b*) *The Final Analysis Book.* The book is divided into sections for each particular vegetable, *e.g.* one section is devoted to all varieties of tomato. Each planting is recorded in chronological order and these records give indications of the relative merits of the different varieties.

(*c*) *The Record of Manures Applied.* Records for each bed are inserted on a separate page, and details are given of date, amount and type of artificial fertilizer or compost applied. The complete manurial history of each bed is thus available at a glance.

(*d*) *The Crop Book.* This is basically similar to (*c*), being a chronological record of the crops grown in each bed. By combining (*b*) and (*c*) the complete cropping history of any bed can be traced. This will be invaluable in assessing the long term effects of the inter-relationships between the various crops.

The results obtained from various crops studied at Enugu will now be considered in more detail.

The tomato

In the first year it became obvious that certain varieties of tomato were very susceptible to climatic conditions and in the period under review 23 varieties have been tried. Seed has been obtained from various sources, viz., England, South Africa and the United States of America, and in most cases the acclimatized seed has been tested against newly imported seed of the same variety and, as far as possible, throughout all seasons. Of the 23 varieties, only six have proved sufficiently tolerant of the climatic conditions to warrant further long term testing and the characteristics of these may now be considered in more detail.

Dwarf Gem. Of all the Stonor varieties so far tested only Dwarf Gem and Moneymaker have proved suitable for commercial production at Enugu. The value of Dwarf Gem lies in its ability to give high yields in a short growing period, while the absence of side-shoots renders it particularly suitable for growers with little previous experience in tomato work. A further point in favour of Dwarf Gem is the flavour and uniform size of the fruit, which is highly appreciated by local consumers. It will be seen from *Figure 1A* that production is highest from plantings made between July and September. Fruit from these plantings would normally be available on the market during October and November which, in Eastern Nigeria, is a month after the peak production from local growers, a factor of obvious commercial importance.

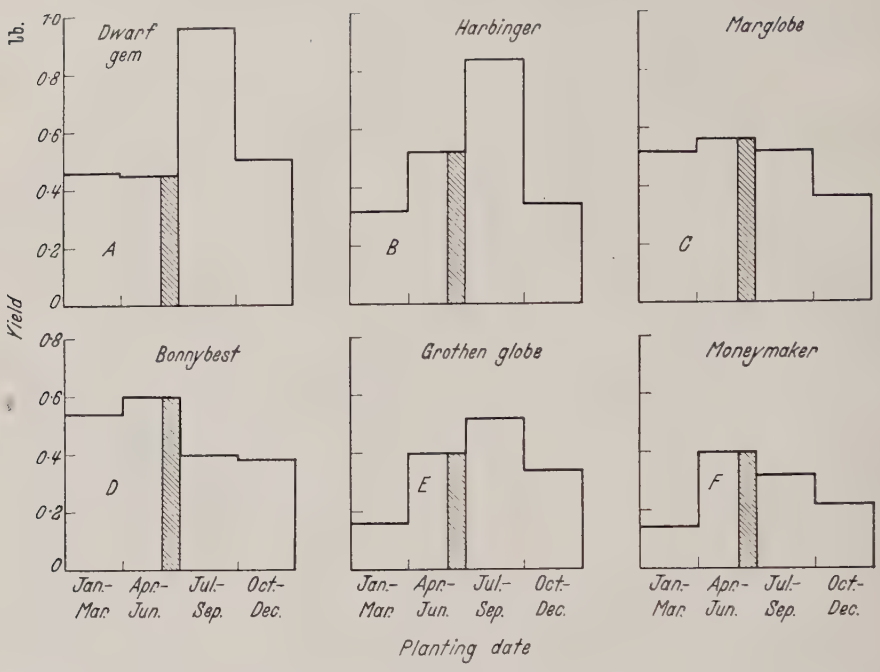

Figure 1. Variations in yield of tomato varieties with planting date (4- or 5-year averages) ; the hatched areas represent peak planting dates of local growers

Harbinger is a variety that demands a higher standard of husbandry than Dwarf Gem in that the single stem method of cultivation, in which side-shoots are removed, is to be preferred. It might here be mentioned that it is not a common practice amongst local growers to remove the side-shoots from tomato plants, which are allowed to assume their natural habit.

It is a highly productive variety, but during the height of the rainy season a proportion of the fruit is lost owing to splitting. This splitting can be avoided by harvesting the fruits in a half-ripe state, but this has an adverse effect on flavour and skin texture. 'Stopping' after the third truss has been found economic, since later trusses mature more slowly. The adoption of this practice enables beds to be cleared between 16 and 18 weeks after planting. As with Dwarf Gem, production is highest from plantings made in the period July to September, so that the peak yields are obtained from September to December, *i.e.* in the transitional period between the end of the rains and the beginning of the dry season (*Figure 1B*). The fruit, while larger than that of Dwarf Gem, is regular in size and finds a ready market.

Grothen Globe is a useful variety and similar to Dwarf Gem in producing its maximum yields later than the indigenous Nigerian varieties (*Figure 1E*). The fruits are somewhat irregular in shape and are larger than in the other varieties. Plantings made throughout the dry season do not give commercially valuable yields.

Moneymaker appeared to be the most promising variety during 1951 and 1952, but its susceptibility to blossom end rot has rendered it unsuitable for

commercial production on soils with a low calcium status such as occur at Enugu. During 1952 all stocks of this variety became infected by a virus complex, with symptoms resembling those of tobacco streak. It is interesting to note that disease symptoms appeared simultaneously in plants raised from acclimatized seed and from seed freshly imported from two sources in England. Similar outbreaks occurred in stocks of this variety grown elsewhere in the Eastern Region. It was therefore considered advisable to limit plantings of this variety, even though the fruit size, flavour and texture were excellent. Its yielding characteristics can be seen in *Figure 1F*.

Marglobe, an American variety, has proved particularly tolerant of the wet and dry season conditions, and although its peak yields are less than Dwarf Gem and Harbinger, planting date is of less importance (see *Figure 1C*). The large fruit size enjoys only a limited popularity amongst buyers. As with most American varieties, the fruits are firm and the fruit/seed ratio is higher than that usually encountered in varieties of English origin.

Bonny Best is similar to Marglobe but tends to produce a higher percentage of second grade fruits. Its particular value lies in the relatively high yields obtained from plantings made during the dry season (*Figure 1D*).

The seasonal variations of yield with planting date, have been averaged for all the six varieties mentioned above. As might be expected, peak production is obtained from plantings made in July, August and September, while yields from the plantings made at the beginning and end of the year are somewhat lower, but by a judicious choice of variety and attention to planting date it is possible to maintain a consistently high yield throughout the year. Mention might here be made of the fact that so far no variety resistant to *Cladosporium* leaf mould has been found; varieties obtained from Cheshunt, which had been specially bred for resistance to leaf mould, quickly became infected when grown at Enugu.

There is evidence to suggest that during the period under review there has been a steady increase in average yield per plant. This may be associated with (*a*) progressive increase in the fertility of the beds, due to the cumulative effects of application of night-soil compost and artificial fertilizers, (*b*) use of the higher yielding varieties and (*c*) increased efficiency of the Nigerian personnel, who are now conversant with the routine cultural practices that are so essential to commercial production.

During the next few years particular attention will be paid to the control of blossom end rot, the more rigorous testing of varieties and the selection of a strain particularly adapted to West African conditions.

Beans

The demand for the French bean, *Phaseolus vulgaris*, exceeds that for all other beans. Of the varieties tested at Enugu, Canadian Wonder has given higher average yields than The Prince, Contender, Bush Logan and Full Green. Keeney's Stringless Greenpod Refugee, a variety particularly suitable for the canning industry, failed to give commercially profitable yields. During the last five years, experience has shown that plants grown from seed newly imported from South Africa and England have given higher average yields than those obtained from acclimatized seed sown at the same time. There are indications that, even with the most rigorous

selection, acclimatized stocks lose vigour after the F_3 generation, and only once has it been possible to select up to the F_6 generation; this was in the case of a single plant selection line. It has been necessary to import fresh stock seed of Canadian Wonder by air at frequent intervals in order that adequate stocks of F_1 and F_2 seed are available for local growers and for planting at the market garden. Air transport was employed to minimize the loss in vitality experienced with sea mailings. This extra cost of air transport and the progressive loss in vigour in acclimatized stocks has so far rendered the commercial production of the dwarf varieties impracticable. An additional factor which has recently become apparent is that dwarf varieties appear to have little resistance to root knot nematodes. It might be mentioned here that it is not definitely known whether the normal nitrogen-fixing organisms usually associated with beans growing under temperate conditions, are in fact present in the market garden soil. An attempt to gain some information on this important fact was made in 1953, when a small quantity of commercial bacterial inoculum was imported from South Africa. Inoculated seed was planted in beds in various parts of the market garden and plants from treated seed were noticeably more robust and flowered earlier than the controls. Unfortunately all inoculated plants died prematurely, immediately after the flowers had set, but the reasons for this disappointing result are not known. The fact that the trial took place in the middle of the dry season may be of significance. It is proposed that another trial, using more critical techniques, be conducted in the near future under wet season conditions. Other aspects of the nodulation problem are discussed in the section dealing with mineral disorders.

The lack of success with the dwarf varieties of French bean, led to consideration being given to the climbing varieties. Of these, two strains had been separated, one black seeded and the other white seeded. Stocks of both of these strains have been grown at Enugu since 1952 and there has been no appreciable loss of vigour. The average yields of both strains cannot yet be considered of commercial value, but it must be stated that yields are increasing progressively with selection, and this fact, together with the apparently lower susceptibility of the varieties to nematode infestation, gives promise of better results in the future.

The Lima bean, *P. lunatus*, of which four varieties have been tested, is grown on a small scale by local farmers, the dried beans being used in soups. At the market garden, the pods are harvested green and are acceptable as a substitute for broad beans. The seed of the Pole Lima and Henderson's Bush Lima, from which all present stocks are derived, was American in origin. Later importations made in 1954 germinated so poorly that it was not possible to assess the difference in yields between stocks grown from imported and acclimatized seed.

Information shows that yields from the pole variety are greater than those obtained from the bush variety and the average yields of pole lima from 1951 to 1954 are given in *Table 2*.

These yields, expressed on an acreage basis, range from 1,000 lb. to 5,800 lb. per acre, and as local farmers only expect a maximum yield of 500 lb. dried beans per acre, the economic value of night-soil compost is at once apparent.

Table 2. Average yield of Pole Lima beans (lb. green pods per plant)*

Year	*Jan.–March*	*April–June*	*July–Sept.*	*Oct.–Dec.*
1951	0·21	0·12	0·27	0·20
1952	0·69	0·15	0·23	0·14
1953	0·26	0·29	0·31	0·33
1954	0·50	0·39	—	—

* These yields are derived from records of yields from 5871 plants.

The sword bean, *Canavalia ensiformis*, has been grown successfully at the market garden, where it is gathered in the half-mature stage and is then used as a poor substitute for the French bean. Since there is little local demand for the dried beans, its usefulness as a market garden crop depends on the non-availability of French beans, and it is therefore not considered of real value. It is grown to a small extent by farmers in the Eastern Region.

The winged bean, *Psophocarpus tetragonolobus*, has however proved a readily acceptable substitute for the French bean, when picked at the immature stage. This bean has been grown continuously on the market garden for the whole of the period under review and has exhibited a remarkable freedom from disease and a high tolerance of dry season conditions. The yield of dried beans is less than that obtained from the sword bean, and its value when grown as a compound crop will therefore be dependent on the Nigerian accepting its use in the green state.

Lettuce

The climatic conditions of the Eastern Region have always been considered to be unsuitable for the production of the cos type of lettuce, which rapidly 'bolts' under tropical conditions; studies at Enugu have therefore been confined to the cabbage type.

There are two basic types of cabbage lettuce, the 'curled' type, which has crisp leaves with a wavy margin, and the 'butterhead' type, which possesses leaves which are soft, somewhat oily and entire. The curled type can be further sub-divided into the 'heading' and 'non-heading' varieties. The varieties of lettuce grown commercially in the United Kingdom are usually of the butterhead type, but these have not proved suitable at Enugu, except for Golden Ball. This variety has given good results in the dry season, but the soft texture of the leaves, which are easily damaged by the torrential rains, renders it unsuitable for wet season cultivation. For general cultivation throughout the year Sutton's A.1 and Webb's Wonderful have proved superior to all other varieties. The leaves of both of these varieties suffer less damage during the heavy rains owing to their comparative coarseness and their natural habit, which is the formation of a loose heart. American curled varieties, including some which have a reddish tint on the leaves, have not given good results.

It has been the usual practice to drill the seeds in boxes, since white ants cause heavy losses when seeds are sown directly in the beds. Transplanting of seedlings during the dry season has often led to heavy losses. Most of the seed used at, and distributed from, the market garden has been imported from England and South Africa, and except for isolated batches,

germination has been normal. The necessity for producing seed at Enugu became apparent in 1951 and a start was made on selection; so far results have been encouraging.

Carrot

The first sowings made on the market garden at Enugu were from seed produced at Bamenda, and the results obtained proved conclusively that carrots grown from acclimatized seed were degenerate in colour and texture. Seed was then imported from England and South Africa and roots of a satisfactory colour and texture were obtained. The stump rooted varieties Chantenay and Early Nantes have proved more suitable than the longer rooted types of intermediate and main crop carrots, although the latter are grown with more success at Kano and Jos.

Although it is usual to drill the seed directly into the beds at Enugu, there is no evidence to show that transplanting, as carried out by local growers, is detrimental to root development. At Enugu the demand for the small, stump rooted types has been so high that they have often been harvested before the roots have reached their maximum size. This practice has largely minimized the problem of premature 'bolting', of which only isolated cases have been observed. The average yields per bed of 100 square feet are set out in *Table 3*.

Table 3. Yield of carrot (variety Chantenay) for each quarter of 1953 and 1954 (roots per bed of 100 sq. ft.)

Year	*Jan.–March*	*April–June*	*July–Sept.*	*Oct.–Dec.*
1953	48	49	153	84
1954	115	238	127	100

Sweet corn

Throughout the region the main maize plantings are made at the onset of the rains, during March and April, but the conditions are such that late crops are not at present considered profitable by the local farmers.

In the last few years the incidence of maize rust (*Puccinia polysora*) has been high and small compound plantings made after the main plantings have usually given small yields. In the market garden plantings have been continuous throughout the year, but yields are greatest from plantings made between March and June; an appreciable reduction of yield occurs in plantings made at the end of the year.

The main variety grown at Enugu is Golden Bantam, which is particularly susceptible to rust[3], and heavy infection is usually present throughout the year. Stowell's Evergreen, although more resistant to rust, is a white seeded variety and therefore less acceptable to consumers. Varieties of maize which are known to be less susceptible to rust have also been tried. These gave yields averaging over one cob per plant during the main growing season, but did not thrive under out of season conditions.

Another white seeded variety, Country Gentleman, did not give commercially profitable yields, but an American hybrid, Golden Security, gave such good results that many people made special visits to the market garden

to see it. The original seed of this hybrid was imported from America, but the results obtained were merely of academic interest since no facilities for breeding hybrids exist at Enugu. It is interesting to note, however, that seed collected from the first harvest produced a heterogeneous collection of types when planted the following year. This formed an excellent object lesson to trainees and others, in the known behaviour of a selfed F_1 generation of an American hybrid type.

The average yields of green cobs per plant for Golden Bantam and Stowell's Evergreen are shown in *Table 4*, which summarizes two years' results. There are indications that Golden Bantam gives higher yields than Stowell's Evergreen from plantings made during the first half of the year, but the latter variety may be better for planting during the latter half of the year. This conclusion, however, is tentative, and requires confirmation from more detailed work.

There is evidence that the yields obtained from seed newly imported from South Africa are higher than the yields from the same variety grown from acclimatized seed. Germination of Enugu seed has been generally poor from seed harvested at the end of the rains, but the reason for this is obscure.

Table 4. Comparison of yields of two varieties of sweet corn grown at Enugu. (Average No. of green cobs per plant)

Variety	*Year*	*Jan.–March*	*April–June*	*July–Sept.*	*Oct.–Dec.*	*No. of plants*
Golden Bantam	1953	0·54	0·60	0·49	0·18	2,053
	1954	0·98	1·29	0·77	0·44	704
Stowell's Evergreen	1953	0·39	0·38	0·69	0·25	3,358
	1954	0·92	1·00	0·92	0·59	1,676

Onions

During 1950 and 1951 attempts to grow the White Lisbon variety of spring onion failed owing to poor germination of the imported seed, but later results have proved more satisfactory. Seed of several varieties of bulb onion, including Texas Grano, have been imported, but all have failed to produce a high percentage of marketable bulbs owing to premature seeding. A type of bulb onion grown extensively in the Northern Region has given much better results when grown as a bulb onion or when harvested in the young stage, and it has now been possible to produce seed of this type at Enugu. Local growers have been quick to appreciate the commercial significance of the spring onion as a crop and production has increased considerably.

The Brassica *crops*

Little success has been achieved in the production of good cauliflowers, and although many varieties have been tested, only the Indian variety, Early Patna, has produced saleable heads. It is felt that the nutrient requirements of this crop when grown under Enugu conditions might well be investigated more fully, particularly as some local growers obtain excellent results from temperate varieties.

Of the varieties of cabbage tested, the small, quick maturing types have proved more satisfactory than the larger kinds, and of the former the best results have been obtained from Golden Acre and Early Offenham. Difficulties have been experienced from plantings made during the dry season and also from insect attack in the early stages of growth, but the latter trouble has been less pronounced in the two varieties mentioned above. It might here be mentioned that Scotch kale has been grown successfully, but has not proved to be popular.

Several of the Roscoff varieties of broccoli have been tested, but have failed to produce good heads; the purple sprouting type is popular, and although it fails to produce flower heads, the young shoots are in great demand. It has not been possible to obtain seed from any of the above at Enugu, and all stocks have been grown from seed imported from England and South Africa.

Chinese yam and Jerusalem artichoke

Owing to the low altitude, the production of potatoes was not attempted at Enugu, so that it was necessary to consider the possibilities of substitute crops. The Chinese yam, *Dioscorea esculenta*, has proved easy to grow, and the demand for the small, egg-like tubers has been high. The yields obtained at Enugu during the last four years have ranged from 0·74 lb. to 3·69 lb. tubers per plant.

The Jerusalem artichoke has proved attractive to buyers, but the yields have been below those obtained when grown under temperate conditions. The globe type has been tested and rejected as uneconomic.

Herbs

The demand for the commoner culinary herbs has been high and of these parsley, mint and chives have been grown continuously with good results. During the dry season it has been found necessary to grow the plants in pots under shade, as none are tolerant of the hot climate. Of the less common types, dill, borage and thyme have been grown successfully, but sage and horse-radish do not thrive.

Miscellaneous vegetables

With the wide range of vegetables under test at Enugu, it was inevitable that some types which were suited to the climatic conditions would not meet with a ready demand locally, and of these garden egg and snake gourd are typical examples, neither of which have proved popular with buyers. Cucumbers, however, have been in good demand, but owing to heavy infection with mildew, production is not economic. This appears to be a purely local problem as the crop flourishes elsewhere in the region. Sweet peppers and chillies have been grown successfully, and with the former great interest has been shown in the imported varieties, World Beater and Neapolitan. Beetroot, of which only the globe type has been tested, has a limited sale, and the same has been experienced with golden self-blanching celery. The Indian types of spinach, *Basella alba* and *Basella rubra* are worthy of mention, being easy to grow and readily acceptable to buyers, particularly during the dry season when a paucity of other types of green vegetables is usually experienced.

TRAINING

The training of Nigerians in the modern techniques of commercial vegetable growing has always been an integral part of the scheme. The wide range of educational standards found among the trainees led to the adoption of a series of lectures which can be adapted to their individual needs. These lectures are given in conjunction with practical work and cover the following subjects: elementary botany, composition of soils, compost and artificial fertilizers, pests, diseases and control measures. The course is for four months, during which time the trainees are taught the normal cultural practices and actually carry these out under the supervision of trained staff. So far a total of 35 men have successfully completed the course of training, the majority now being engaged in full time vegetable growing, either as owners or managers.

PESTS AND DISEASES

Insect pests

During the first three months after the opening of the market garden at Enugu, it seemed that the insect population was so large and varied that complete control of all the harmful species would be impossible. By far the most troublesome pest was the cricket, *Zonocerus variegatus*; it appears to have decreased in numbers during the period under review, but complete control will not be attained until the area around the market garden, which forms a natural habitat, can be developed. Galuricid beetles have been particularly destructive on okra, causing severe damage to the leaves and heavy losses in yield. Cotton Stainer has also given trouble on the ripe fruits of okra. A fruit borer, probably *Prodenia litura*, has given some trouble on tomatoes. Periodic attacks of blue aphis on turnips have been observed, but have been controlled by spraying. Mealy bug infestation on a ' ratoon ' crop of pineapple was also controlled by spraying. An attack of Army worm in 1950 was controlled before serious damage was done. To sum up, it may be said that *Agrocide* 3 and D.D.T. have so far proved effective against the more serious pests, whilst derris and pyrethrum have been of some value.

Eelworm diseases

There are clear indications that in the market garden soils the eelworm population has increased considerably since 1950. Evidence of nematode damage has been seen on French dwarf beans, tomatoes and carrots, and visual symptoms suggest that eelworms of the root knot type are predominant. A complete study of the nematodes found in the market garden soils would be of the greatest value, since eelworm problems may well become a serious obstacle to large scale vegetable production in Eastern Nigeria.

No effective measures for the control of eelworms have so far been devised. Beds in which beans had been killed by eelworm attack were given a double application of night-soil compost and were rested for three months. Later plantings of beans suffered less damage, and it is possible that the heavy composting reduced the eelworm population. The possibility of using nematicidal fumigants such as Shell D.D. has not been overlooked, but in view of the highly poisonous nature of many of these proprietary compounds, they can scarcely be recommended to local growers as their application usually requires special training and equipment.

Fungus diseases

By far the most important of these is *Cladosporium* leaf mould of the tomato, which is present at Enugu in both wet and dry seasons. In the latter the disease is predominantly a leaf infection, but in the wet season fruits are also attacked. Cucumber mildew is serious enough to be a limiting factor in cucumber production, but the causal organism has not yet been isolated or identified. A suspected *Fusarium* wilt of tomato and egg plant occurs at Enugu and is usually fatal. This problem merits further investigation.

Although attempts have been made to control the above named diseases with various proprietary products, none has so far proved satisfactory. The use of sulphur and sulphur-based sprays has not proved effective against cucumber mildew, and the use of Bordeaux mixture against other diseases has been limited by the absence of a local source of high grade quicklime. It is proposed to make a trial using calcium carbide as a substitute for quicklime during the next rainy season. Other copper-base sprays have given disappointing results and there has been appreciable loss of spray deposits during the heavy rains. This problem can probably be circumvented by the use of a good ' sticker ', but it is felt that more attention should be given to tests of the newer American fungicides of the dithiocarbamate and naphthaquinone types which have given such promising results on the ' truck ' crops in the United States.

Virus diseases

Virus diseases assume greatest importance on beans and tomatoes. In the latter crop, Moneymaker, as previously mentioned on page 25, became infected by a virus complex in 1952 and when the epidemic was at its height 500 plants were rogued and burnt in one month. A leaf mosaic of Lima bean has given cause for concern and attempts are being made to select seed from plants which appear to be resistant. A virus complex which produces symptoms resembling a mixture of leaf curl and the mosaic types is very frequently found in the peppers, but affected plants appear to tolerate the infection. There has been some evidence of a virus disease in isolated plants of lettuce, but no definite information on this is available.

Bacterial diseases

A disease with symptoms similar to those of bacterial wilt recently occurred in French dwarf beans, but this outbreak, which was not widespread, can possibly be attributed to the early onset of the rains.

Mineral disorders

It is probable that in the near future many complex mineral disorders will become evident in the market garden. Almost all the soils in the Eastern Region are notoriously low in calcium and organic matter, and the relation of added calcium to other minerals in ' artificial ' soils of high organic matter content, is a matter which will require considerable study, particularly in view of the fact that most of the crops grown at Enugu are of temperate origin. An example of a disease frequent at Enugu and believed to be associated with a real or induced calcium deficiency is blossom end rot in tomatoes[4,5], mentioned previously on page 24.

Sweet corn grown on the market garden is usually manured with ammonium sulphate only (see *Table 1*) and this has already induced severe potassium deficiency in some plots, due probably to an unfavourable change in the nitrogen–potassium ratio.

Another macronutrient which is known to be in short supply in most of the acid sand soils of the Eastern Region is magnesium. Already symptoms suggestive of magnesium deficiency have appeared on *Bauhinia* trees grown in the market garden as ornamentals, but up to the present no obvious signs of magnesium shortage have appeared in the vegetable garden.

The effect of additions of large quantities of organic matter has become apparent on citrus stocks planted on the lower slopes of the market garden site, where copper deficiency has appeared on young orange and grapefruit trees which have received large dressings of compost. It is interesting to compare this with the so-called ' reclamation disease ' of cereals growing on the peat soils in Holland, where copper deficiency has been shown to be induced by excessively large amounts of organic matter in the soil. Since heavy composting is a necessary feature of the preparation of soils at Enugu, a close watch for copper deficiency is being kept on the vegetable crops.

The possible rôle of the element molybdenum in the promotion of nodulation in leguminous crops[4] has so far received but scant attention in tropical agriculture, where failure of nodulation in legumes has usually been attributed to the absence of a suitable strain of symbiotic bacterium. It is felt that in tropical soils of low *p*H, molybdenum may only be partially available to crops and experiments on the effects of molybdenum on nodulation in particular, and on the growth of leguminous crops in general, would almost certainly produce interesting and perhaps valuable results.

DISCUSSION

It would seem probable that the Eastern Region of Nigeria will follow the pattern of development of many tropical countries in that an increasing urban population will stimulate vegetable production by small growers.

Such development will depend on three factors. First, it will be necessary to train Nigerians in the fullest possible manner, so that they become conversant with the latest refinements of cultural technique in vegetable growing. Secondly, varieties suited to local conditions must be bred *in situ*, or imported. For a really stable market garden industry acclimatized high yielding strains, which will give adequate amounts of seed of uniform performance, must be available. Thirdly, the nutrient requirements of the various crops grown must be thoroughly known, and a means of correcting deficiencies of both macro- and micronutrients must be readily available to local growers.

In the varying terrain of the Eastern Region it is obvious that there will be some variation in the behaviour of the different varieties under different conditions of soil and climate. It will be essential, therefore, to establish trial plots at representative points throughout the region. More attention must be given to propaganda showing the use of the newer types of vegetable, many of which are unfamiliar and often regarded with suspicion by Nigerians.

Finally, it must be stressed that although production may be largely centred around towns, it will be necessary to improve transport, packing

and marketing facilities, which at present are totally inadequate in both quality and quantity.

SUMMARY

Social and economic changes which have taken place during the last ten years in the Eastern Region of Nigeria have caused a sharp rise in the population of the urban areas. This has not been accompanied by a comparable increase in vegetable production. In the Eastern Region the traditional centres of vegetable production are remote from the large towns, and it is essential that vegetable production be stimulated in urban areas.

In 1950 the Department of Agriculture, Eastern Region, initiated the Pilot Urban Market Garden Scheme at Enugu, to investigate problems of commercial vegetable growing in the larger towns, using night-soil compost to maintain soil fertility under conditions of continuous cropping. A very wide range of vegetables has been tested under commercial conditions and already valuable information has been obtained concerning the most suitable varieties. Seed of the latter is now available in sufficient quantities to supply the needs of local growers. The training of Nigerians is an integral part of the Scheme, and so far 35 men have completed the course.

It is hoped that future investigations will include more detailed work on the control of pests and diseases, with particular reference to mineral disorders. Experiments are required to find the optimum fertilizer applications for soil of high organic matter content under conditions of high temperature, while investigations into the factors affecting the decrease in viability during storage of various vegetable seeds would be of immediate economic advantage.

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Virus Diseases of Solanaceous Crops in Trinidad

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The occurrence of tobacco mosaic virus in Trinidad, infecting crops of tobacco (*Nicotiana tabacum* L.), sweet pepper (*Capsicum annuum* L.) and tomato (*Lycopersicon esculentum* Mill.) was reported by W. T. Dale[1] in 1943. Only a single outbreak in tobacco has since been observed. The identity of the virus was readily established from its host reactions and unusually high resistance to dilution, ageing *in vitro*, and heat (expressed sap remaining infective after 10 min. at 90°C).

Cucumber mosaic virus seems to have become increasingly common in tobacco, during the past few years in the St. Augustine area at least. Although it infects cucumber (*Cucumis sativus* L.) and certain weeds, *Petunia hybrida* Vilm. is the only other member of the Solanaceae so far found naturally infected. The symptoms produced in tobacco are very similar to those of tobacco mosaic, but the viruses can be readily distinguished by the reactions they induce in other hosts (see below) and by the much lower resistance of cucumber mosaic virus to dilution, ageing *in vitro*, and heat (all infectivity in expressed sap being destroyed after 10 min. at about 65°C). The identity of Trinidad isolates was conclusively proved by protection experiments, using Price's indicator strain of the virus[2].

Pepper vein-banding virus commonly infects all types of peppers (*Capsicum annuum* and *C. frutescens* L.) and has been found in tobacco. This virus is probably related to the one described from Puerto Rico by A. Roque and J. Adsuar[3], and possibly to one in Brazil[4]. Eggplant mosaic virus commonly infects eggplants, and occasionally spreads into adjacent tomatoes. It shows similarities to tobacco ring-spot virus and potato virus X, being probably nearest to the former, which has been reported to attack eggplants in Texas[5]. The characteristics of pepper vein-banding and eggplant mosaic viruses have already been described in some detail[6]. Both are sap-transmissible, the latter most readily so. They show no immunological relationship to each other, nor to tobacco or cucumber mosaic viruses.

I. A. C. Ferguson[7] briefly described two diseases of tomato which he called 'twisted-leaf' and 'bronze-leaf', and attributed to viruses. The former is very common and has been recognized as a virus infection for at least twelve years; the condition described by R. E. D. Baker[8] as 'wet weather disease' was due, in part, to this virus, which is not sap-transmissible though readily transmitted by grafting. The latter is almost certainly not due to a virus but to mites. A similar disease also affects peppers. As these symptoms associated with mites may be mistaken for those of viruses, they are discussed in the final section of this paper.

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SYMPTOMS AND HOST RANGES

Tobacco mosaic virus

Field symptoms seen on tobacco and tomato in Trinidad were typical of the widespread mild green-mottling strains. During greenhouse experiments an isolate producing marked leaf-crinkling in tobacco and abnormal leaf shape in tomato was obtained. Yellow flecks were also commonly seen on systemically infected hosts, indicating the presence (as is usual with this virus) of yellow strains in localized areas. Vein-clearing was followed by chlorotic leaf-mottling and flower, fruit and leaf shedding in most varieties of *Capsicum annuum*; but a type of immunity has been encountered, resulting from localization of the virus in inoculated leaves and sometimes adjacent ones also, which are then shed. This reaction is well-known[9,10], being governed by a single gene (L) dominant over the one for mottling (l). No other plants were found naturally infected in Trinidad, although the virus is known to have a wide host range, and various species were artificially infected in the greenhouse.

Eggplants of the imported Black Beauty variety, if inoculated when young, gave necrotic local lesions only, and became immune to the virus when more than a few weeks old. The lesions attained about 4 mm in diameter, and when numerous the entire leaf was often destroyed. Local eggplant types usually gave the same reaction, but the virus occasionally persisted systemically, producing an almost imperceptible mottling. A strain of tobacco mosaic virus studied by G. C. Ainsworth[11] produced systemic mottling, malformation and stunting of eggplant, while F. O. Holmes[9,12] found some varieties symptomless carriers, or virtually so, but obtained systemic necrosis of Black Beauty. The isolates of Holmes, however, were rather virulent and gave necrosis of petioles and stems in *Nicotiana glutinosa* L., in addition to the local lesion reaction characteristic of green-mottling isolates such as the Trinidad ones. The latter produced local lesions on *Phaseolus vulgaris* L. and gave the characteristic reactions of the virus on petunia (*Petunia hybrida* Vilm.), *Nicotiana chinensis* Fisch. (coarse mosaic in both) and *N. rustica* L. (local lesions followed by widespread necrosis).

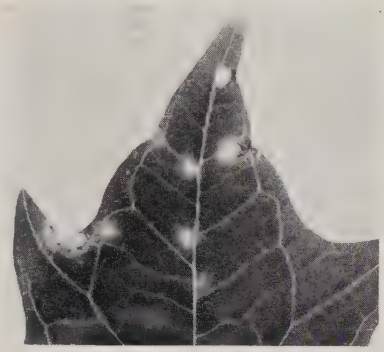
At greenhouse temperatures of 23 to 31°C., local lesions appeared on hosts giving this reaction, in two to three days, and vein-clearing in as little as four days on actively growing plants.

Cucumber mosaic virus

This causes an irregular mosaic of field tobacco, not unlike that due to tobacco mosaic, but characterized by more yellowing, particularly of the lower leaves. There is no obvious stunting. Plants have been found naturally infected by the cucumber mosaic and pepper vein-banding viruses simultaneously. In these, young leaves exhibit irregular chlorotic vein-banding, and older ones discontinuous and blotchy green vein-banding, the interveinal areas being yellow. Young White Burley tobacco plants, when inoculated with cucumber mosaic virus, gave numerous chlorotic local lesions of 2 to 3 mm diameter in three to four days. Sometimes these took the form of chlorotic rings with darker green centres; not infrequently they finally became necrotic. Vein-clearing of the youngest leaves appeared a few days after the local lesions, and this changed to a mosaic pattern,

sometimes tending towards broad dark green vein-banding. The final greenhouse symptoms (*Figure 1a*) resembled those due to tobacco mosaic virus, although the latter gave sharper delineation of the boundaries between light and dark green areas, and more blistering of the lamina. The two viruses can be readily differentiated by the reactions of other hosts. *Nicotiana glutinosa* reacted to cucumber mosaic virus by systemic

(*a*) *Systemic symptoms on tobacco*



(*d*) *Necrotic local lesions on* Chenopodium hybridum

(*b*) *Coarse mosaic and blistering on* Nicotiana glutinosa

(*c*) *Coarse mosaic on* Zinnia elegans

Figure 1. Symptoms of cucumber mosaic virus

symptoms; most isolates from field tobacco gave coarse mosaic and blistering (*Figure 1b*) in four to ten days, sometimes preceded by transient vein-clearing; but a strain producing a fairly marked vein-banding phase has been obtained. *N. rustica*, *N. alata* var. *grandiflora* Comes, *N. chinensis*, *N. sylvestris* Speg. & Comes and *N. tabacum* var. *macrophylla* (an ornamental tobacco) also developed systemic infection.

A few local lesions similar to those on tobacco, followed by vein-clearing, coarse mottling and some leaf-crinkling, characterized the artificial infection of petunia. In plants naturally infected out of doors, chlorotic vein-banding and leaf-crinkling are the predominant symptoms. Tomato (var. Winsall) gave coarse mottling and twisting of the young leaflets, but little stunting. Peppers (var. Fordhook, Puerto Rico Wonder and Large Bell Hot) developed chlorotic local lesions, quickly followed by vein-clearing, puckering of the expanding leaves and mosaic. *Physalis floridana* Rydb. reacted by vein-clearing, and then coarse chlorotic mottling, crinkling, reduction of leaf size and stunting. On eggplant the virus produced a few faint chlorotic local lesions, and areas of faint chlorotic vein-banding sometimes appeared on a few leaves.

Isolates from naturally infected tobacco or cucumber, though not identical, gave similar symptoms when inoculated to cucumber. Vein-clearing appeared in four to eight days, and very numerous small chlorotic spots, associated with the veins, soon developed, followed by coarse chlorotic mottling and crinkling of the leaves. A few large chlorotic local lesions were produced on the cotyledons of pumpkin (*Cucurbita pepo* L.), but no further symptoms. *Zinnia elegans* Jacq. gave coarse light and dark green leaf-mottling (*Figure 1c*), sometimes preceded by slight transient vein-clearing. When infected and uninfected plants were inoculated with Price's indicator strain of cucumber mosaic virus[2], only the latter developed the characteristic dark brown local lesions, confirming immunologically the identity of the Trinidad virus.

Chlorotic local lesions developed on *Chenopodium hybridum* L. after three days, but no systemic invasion occurred. The lesions usually became water-soaked, and finally pale brown and necrotic in about seven days, reaching 4 to 5 mm or more diameter (*Figure 1d*); D. A. Roberts, R. E. Wilkinson and A. F. Ross[13] obtained the same symptoms on this plant with all tested cucumber mosaic virus strains. The virus could be recovered from inoculated celery (*Apium graveolens* L.) which, under greenhouse conditions at least, is a symptomless carrier. The formation of small reddish necrotic local lesions on the primary leaves of cowpea (*Vigna unguiculata* (L.) Walp.) is characteristic of many strains of cucumber mosaic, but the reaction is erratic. None were produced by Trinidad tobacco isolates on either Black-eye cowpea or a black seeded variety. *Phaseolus vulgaris* also gave a negative reaction. K. S. Bhargava[14] found that in England this host gave local lesions with four strains of cucumber mosaic virus, but only during the winter; failure to develop in Trinidad is therefore not surprising.

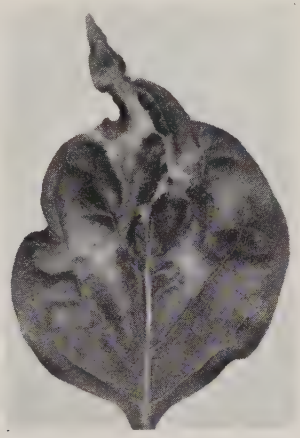
Strains of cucumber mosaic virus resembling those in tobacco have been isolated from two common weeds of cultivated land, *Commelina diffusa* Burm. f. and *C. elegans* H.B.K. (*C. nudiflora* L.), showing coarse light and dark green mottling. The importance of the latter as a reservoir host of a celery strain

in Florida was demonstrated by S. P. DOOLITTLE and F. L. WELLMAN[15]. There are other potential wild hosts in Trinidad, such as *Alternanthera ficoidea* (L.) R. Br., which is known to be susceptible.

Pepper vein-banding virus

On the leaves of most pepper varieties (*Capsicum annuum* and *C. frutescens*) this sap-transmissible virus[6] causes an irregular and somewhat discontinuous dark green vein-banding, often bordered by chlorotic areas which merge into darker interveinal tissue (*Figure 2a*). This mottling may be accompanied by crinkling (*Figure 2b*) and reduction in size of the lamina. Intensity of symptoms depends on the pepper variety and the environment, though strains of the virus differing in virulence may exist. Infection of most

(*a*) *Broken vein-banding on Fordhook*



(*b*) *Mosaic and crinkling on Fordhook*

(*c*) *Vein-necrosis on Large Bell Hot*

Figure 2. Symptoms of pepper vein-banding virus on peppers

large fruited sweet peppers (*C. annuum* var. *grossum*), such as Fordhook or California Wonder, causes stunting of the plant. A sweet pepper called Puerto Rico Wonder was bred for resistance to the pepper mosaic of Puerto Rico, by incorporating the resistance of a Mexican pungent variety into California Wonder[3,16], and this new variety has been obtained through the kindness of Dr Adsuar. It also shows resistance to infection by the Trinidad virus, and when infected gives only mild leaf symptoms. If the rubbing method of inoculation is used, with carborundum powder as an abrasive, this resistance is not evident, 100 per cent infection being normally obtained; but when 12 plants each of Puerto Rico Wonder and Fordhook were inoculated by 'painting' their leaves with infective sap, the method used by Roque and Adsuar[3], only one plant of the former against nine of the latter contracted the disease. Some Trinidad red and yellow fruited hot peppers (*C. annuum* var. *minimum*) also seem to be both resistant and tolerant to the virus, leaf symptoms being mild and no stunting of the plant evident. Perennial small fruited bird peppers and cherry peppers (*C. frutescens*) may show marked leaf symptoms but no other obvious damage. The Large Bell Hot variety of *C. annuum* was obtained from Puerto Rico for testing, because of its very characteristic response to the pepper mosaic there[3]. It reacts similarly to pepper vein-banding, suggesting that the two viruses are related. Young plants develop dark brown vein-necrosis of the leaves four to eight days after inoculation (*Figure 2c*) followed rapidly by necrotic streaking of the stem and abscission of all but the oldest leaves, culminating in death. Older plants develop general chlorosis, necrosis of the active shoots and fruit shedding, but may survive in a moribund condition for some time. An additional type of response occurs in some F_1 hybrids between Fordhook or Puerto Rico Wonder and Large Bell Hot. Affected plants are stunted and produce little or no fruit; the leaves are small, mottled and curled downwards, and show varying degrees of vein-necrosis. The genetics of these reactions are being investigated at the Imperial College of Tropical Agriculture.

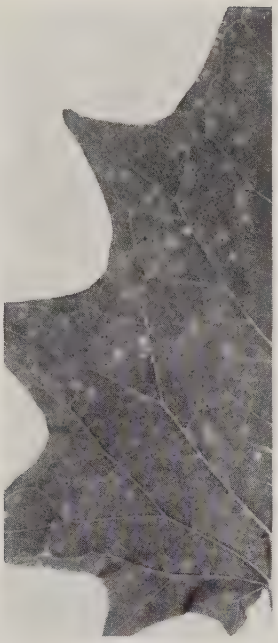
Infected field tobacco shows dark green blotches, sometimes ill-defined, along the veins. Young White Burley plants inoculated in the greenhouse developed vein-clearing, followed by discontinuous dark green vein-banding, sometimes bordered by chlorotic areas which merged into the normal leaf colour. Symptoms of a similar type, though in some instances milder, were produced on other tested *Nicotiana* spp., *Physalis floridana*, and petunia.

Tomato, eggplant, and all tested plants outside the Solanaceae could not be infected by the vein-banding virus, the host reactions of which are described more fully elsewhere[6].

Eggplant Mosaic virus

This is more readily sap-transmissible than pepper vein-banding or cucumber mosaic, but less so than tobacco mosaic. Yellowish local lesions, up to 3 mm in diameter, often appeared on inoculated eggplants after two to four days. Vein-clearing of the expanding leaves, including the inoculated one if small, appeared in four to eight days, followed by mottling which finally took the form of broad irregular dark green vein-banding. Variation

(*a*) *Mosaic on eggplant—more intense than usual*



(*c*) *Systemic ring-spots on* Chenopodium hybridum

(*b*) *Local lesions, systemic ring-spots (with necrotic centres) and chlorotic vein-banding on* Nicotiana glutinosa

Figure 3. Symptoms of eggplant mosaic virus

in symptom intensity occurs, especially in the field. Sometimes the leaves show only faint mottling and at others, the interveinal areas, of lower ones in particular, become quite yellow (*Figure 3a*). The infection of young plants causes a temporary growth check, but there is no evidence of reduction in final size or yield.

The inoculation of tomato or *Lycopersicon pimpinellifolium* Mill. produced chlorotic local lesions about 6 mm in diameter, with indefinite margins. Vein-clearing occurred a few days later, followed by light and dark green mottling and slight leaf-crinkling. This virus stunted tomatoes more than tobacco mosaic virus or isolates of cucumber mosaic virus from tobacco. The few tomatoes found naturally infected also harboured the twisted-leaf virus[7]. The double infection severely stunted the plants, leaves of which were curled and showed whitish-yellow interveinal flecks.

The Arran Pilot potato (*Solanum tuberosum* L.) (a crop which cannot be successfully grown in Trinidad) gave a few circular chlorotic local lesions, which later became necrotic. The next few leaves to expand showed similar but more numerous ring-spots, some of which also turned necrotic. Subsequent leaves became faintly mottled, but it is not certain that this was due to eggplant mosaic virus. Inoculated leaves of pepper (var. Fordhook, Puerto Rico Wonder and Large Bell Hot) developed irregular yellowish local lesions. In petunia, chlorotic local lesions were followed successively by yellowish vein-banding and coarse light and dark green leaf-mottling, the latter ultimately tending towards dark green vein-banding. Yellow local lesions and fairly mild coarse mottling developed on *Physalis floridana*.

Nicotiana glutinosa first gave circular yellowish local lesions, which usually soon turned whitish and necrotic. They were often followed by chlorotic ring-spots, commonly becoming necrotic or partially so, on one or more leaves above the inoculated ones (*Figure 3b*). A few days later, the young leaves usually developed bright yellow vein-banding (*Figure 3b*), which turned into light and dark green mottling tending towards irregular dark green vein-banding (see also Figure 3a, b and c in Dale[6]). The plants became stunted, particularly if inoculated young. When inoculum was obtained from long infected eggplants, particularly old plants in the field, few local lesions developed, and sometimes only ring-spots or no systemic symptoms; on the other hand, juice from recently infected eggplants usually induced many local lesions followed by yellow vein-banding.

Young White Burley tobacco plants developed circular chlorotic local lesions, 1 to 3 mm in diameter, sometimes with necrotic margins. No further symptoms appeared and the virus was not recovered from uninoculated leaves. Older or poorly growing plants gave no lesions.

Chenopodium hybridum gave small necrotic local lesions and systemic chlorotic ring-spots, sometimes turning necrotic from their centres (*Figure 3c*). The systemic spots were few on young leaves, but became numerous as these matured, and sometimes coalesced to give yellowish mottling. The primary leaves of young Black-eye cowpeas developed small reddish-brown necrotic spots. The virus was recovered from the inoculated leaves of cucumbers, which remained symptomless, but celery, pumpkin and zinnia

were not infected. The host reactions of eggplant mosaic virus have been more fully described elsewhere[6].

Twisted-leaf virus

This is very widespread in Trinidad, particularly in areas where successive crops of tomatoes are grown on a relatively large scale. Plants may be affected at any stage in their development; but most commonly the disease appears shortly after transplanting, when the plants are 1 to 2 ft. high. Following the appearance of one or two infected plants the disease usually spreads rapidly through the crop. The first symptom is a sudden check to growth; internodes and petioles are shortened, the leaf rachides become twisted downwards and the leaflets curled, reduced in size and paler in colour than normal. Leaflets expanding at this stage may show a bright yellow vein-clearing, but this symptom is not always present. On the Ponderosa variety necrosis along the veins may produce a purplish-brown net-work, but on Marglobe, Bonny Best, or Winsall vein-necrosis is usually slight. Several days after the appearance of these initial ' shock ' symptoms growth is resumed. Infected plants usually reach normal height but have a less robust habit than healthy ones. Their leaves remain smaller than normal and show interveinal chlorosis. Some variation in symptoms occurs even between plants of the same variety. Experimentally infected plants growing under reduced light intensity in the greenhouse showed little stunting or curling, but the characteristic chlorotic pattern on the leaves was clearly expressed. Similar symptoms were induced on hybrids between tomato and *Lycopersicon pimpinellifolium.*

The twisted-leaf virus is not sap-transmissible, but is readily transmitted by grafting, the first symptoms appearing within one to two weeks. Ferguson[7] claimed to have transmitted it to sweet pepper, but this has not been verified. No other hosts are known.

Several tomato virus diseases, reported from various countries, have symptoms resembling twisted-leaf, which appears to be most like tomato bunchy-top disease in Africa[17,18], and two Brazilian tomato diseases[19,20]. Relationship between the Trinidad and African viruses is doubtful, since the latter is sap-transmissible. The Brazilian viruses cause indistinguishable symptoms in tomato, and they have been classified as varieties *solanacearum* and *braziliensis* of the sugar beet curly-top virus[20]. The former has a restricted host range, its only known hosts being tomato, *Lycopersicon pimpinellifolium*, *Datura stramonium* and *Solanum nigrum* L.; the variety *braziliensis* has a wide host range covering several plant families, but apparently cannot infect *S. nigrum.* The viruses also have different leafhopper vectors. No symptoms suggestive of curly-top infection have been observed in Trinidad on plants other than tomato, so the local virus is more likely to be related to the *solanacearum* variety. One of the proved vectors of this, *Agalliana sticticollis* (Stahl), has been recorded from the island[21]. Discovery of the vectors and elucidation of the host range of the Trinidad virus would provide better evidence of its relationships.

TRANSMISSION

H. J. Walters[22] has shown that the grasshopper *Melanoplus differentialis* (Thos.) can transmit tobacco mosaic in the United States of America, and

a few other insects have been reported as occasional vectors; man is usually considered the chief agent of dissemination, the virus being readily spread by ' topping ' and other cultural practices. This is supported by experience in Trinidad, where, in view of the constant presence of susceptible crops and potential wild hosts, it is difficult to explain the rare occurrence of tobacco mosaic unless efficient vectors are absent. The sporadic infections observed probably resulted from separate introductions of the virus with cured tobacco, in which it readily survives.

The cucumber mosaic and pepper vein-banding viruses, being much less readily sap-transmissible than that of tobacco mosaic are unlikely to be spread by cultural operations; but the commonest Trinidad aphid, *Aphis gossypii* Glov., which feeds on a wide range of plants, is an efficient vector of both capable of acquiring or passing on virus during feeds of a few minutes' duration. Consequently, it is not surprising that dual infections with the two viruses have been observed in tobacco. The only known vectors of eggplant mosaic are flea-beetles (*Epitrix* spp.). These do not transmit the virus very readily and soon lose their infectivity, though being very active and abundant they may play a major part in dissemination of the disease. If, as seems probable[6], eggplant mosaic virus is related to either tobacco ring-spot virus or potato virus X, there may be other biting-insect vectors. H. J. Walters[22] has shown *Melanoplus differentialis* to be a vector of both these viruses in the United States of America. Eggplants in Trinidad are very commonly infested by *Aphis gossypii*, but all attempts to transmit eggplant mosaic with this insect were unsuccessful.

Judging from its rate of spread, the unknown vectors of twisted-leaf are very efficient. There is no evidence of seed transmission with either this or the four sap-transmissible viruses.

ECONOMIC IMPORTANCE AND CONTROL

Very little tobacco is grown at present in Trinidad, though trials are in progress to find out if conditions are suitable for its cultivation on a larger scale. Tobacco mosaic causes serious loss to tobacco growers elsewhere, and it can do considerable damage to peppers. The common green-mottling strain has little effect on the growth of tomato plants, though yields are appreciably reduced[23,24]. Control measures have been summarized by K. M. Smith[25] and F. O. Holmes[26]. Resistant varieties of tobacco[27–29] and pepper[9,10] have been obtained. Avoidance of smoking or chewing tobacco while handling susceptible crops would be a wise precaution against the initiation of outbreaks in Trinidad.

Should tobacco cultivation in Trinidad be expanded cucumber mosaic virus could become a troublesome pathogen. It is probable that other crops, for example peppers and tomatoes, shown to be susceptible to local strains in greenhouse tests and attacked by the virus elsewhere, develop natural infection. Clean cultivation should give some control, due to both elimination of reservoirs of virus and reduction of vector populations.

Eggplant mosaic virus seems to produce no serious effects on eggplants and seldom affects tomatoes, so no control measures directed primarily against the virus are justified; although as *Epitrix* spp. and other insects can cause severe leaf damage insecticidal dusting may sometimes be advantageous.

The effect of infection with the eggplant mosaic and twisted-leaf viruses, separately and in combination, on the yield of Marglobe tomatoes was investigated by a field experiment during the dry season, when tomatoes are most commonly grown. Plants were infected, as appropriate, with eggplant mosaic (by rubbing) or twisted-leaf (by grafting), soon after planting out in the field. Eggplant mosaic alone, and the two viruses jointly, caused statistically significant reductions in mean yield per plant of 25 per cent and 46 per cent respectively. Twisted-leaf virus alone appeared to reduce the mean yield by 6 per cent in this experiment, the reduction being non-significant. This virus, however, quickly spread to almost all plants during the course of the experiment, which probably led to underestimation of both the yielding potentiality of healthy plants and the reduction caused by the virus. Until more is known about twisted leaf, and in particular the method of spread, control measures cannot be suggested with much confidence. Roguing infected plants is unlikely to be of much avail. When avoidable, new crops should not be planted near to heavily infected existing ones, a precaution which applies equally to the other viruses described in this paper.

Pepper vein-banding virus is of no importance as a tobacco disease at present as it rarely affects the crop and produces only mild symptoms. Although very often infected, the local pungent peppers (*Capsicum annuum* var. *minimum* and *C. frutescens*) are tolerant. Perennial bird peppers (*C. frutescens*) are often found growing wild or semi-wild around gardens or abandoned cultivations, and constitute reservoirs from which the virus may spread into the more susceptible sweet peppers (*C. annuum* var. *grossum*). The fact that these are cultivated throughout the year also facilitates the spread of infection. Most sweet pepper seed is imported into Trinidad from the U.S.A. and the available varieties vary; Fordhook was commonly grown a few years ago, but California Wonder seems to have become more popular recently. The resistance to infection with vein-banding virus shown by Puerto Rico Wonder suggested that it might be a good variety under Trinidad conditions. It has therefore been compared in four trials with the other two varieties mentioned.

Sweet pepper yield trials

The comparative yields of Puerto Rico Wonder and Fordhook, and the effect of virus infection on cropping were investigated in two randomized block pot experiments out of doors, the results of which have been statistically analysed together. A block consisted of a 'healthy' and an 'infected' plant of each variety, and there were nine replications in each experiment. The 'infected' plants were mechanically inoculated when about 6 in. high. The number and weight of fruit were recorded for each plant, and the results are summarized in *Table 1*.

Puerto Rico Wonder outyielded Fordhook in both the 'healthy' and 'infected' categories, the least significant difference in yield per plant (at the 5 per cent level) being 67 gm. 'Healthy' and 'infected' plants of the former, taken together, gave 32 per cent more fruit by weight than those of the latter, this difference being significant at the 1 per cent level. The effect of infection on yield appeared to be less marked, but 'healthy' plants

Table 1. Combined yield data for pot experiments

		Mean number of fruits per plant	*Mean fruit weight* (gm)	*Mean yield per plant* (gm)
Puerto Rico Wonder	*Healthy*	8·6	40·2	346
	Infected	7·4	39·2	290
Fordhook	*Healthy*	6·9	38·0	262
	Infected	6·3	34·8	220

of the two varieties, taken together, yielded 304 gm per plant as against 255 gm for ' infected ' plants, the least significant difference (at the 5 per cent level) being 47 gm. The effect of infection on fruit number may be more important than that on fruit weight, since the former was reduced by 12 per cent and the latter by only 5 per cent. The apparently similar yield reduction of about 16 per cent in both varieties was unexpected, in view of the much milder symptoms shown by Puerto Rico Wonder. But there is reason to believe that another factor may have influenced this result: in spite of weekly spraying with nicotine sulphate solution, in an attempt to eliminate insect vectors, a number of controls became infected before the experiments were completed; and due no doubt to their greater susceptibility to infection most of these were Fordhook plants—a fact which would lead to underestimation of both the effect of virus on yield and the yielding ability of healthy plants in this variety.

Puerto Rico Wonder and California Wonder were compared in two randomized block field experiments. In each, a block consisted of two eight-plant plots, to which the varieties were assigned at random, and there were nine replications. Virus infection did not appear in the first experiment for at least 12 weeks, and much of the crop was set in dry weather. Puerto Rico Wonder outyielded California Wonder, giving a greater number of slightly larger fruits. The differences in mean number and weight of fruit per plant were both significant at the 1 per cent level (*Table 2a*). The fact that more California Wonder plants survived until the end of the experiment contributed to this result, but most of the deaths in both varieties occurred at a late stage, after the plants had produced varying amounts of fruit. In the second experiment, all plants were artificially infected with the vein-banding virus before planting out in the field, which coincided with the onset of the wet season. The almost negligible yields obtained from both varieties were doubtless more attributable to the weather than to virus infection. Puerto Rico Wonder again outyielded California Wonder, however, producing more numerous and slightly larger fruits. The differences in mean number and weight of fruit per plant were significant at the 5 per cent and 1 per cent levels respectively (*Table 2b*). Plants died throughout the experiment, and this time poorer viability contributed substantially to the inferior performance of California Wonder. Under the prevailing conditions infected plants of this variety became very chlorotic.

More useful data might have been obtained from the two field experiments but for the writer's departure from Trinidad soon after the second had been started. This also precluded further experiments to elucidate the effect of virus infection on yield.

Table 2. Yield data for field experiments
(a) First trial, 9 April to 29 Sept., 1953

	**Mean number of fruits per plant*	*Mean fruit weight* (gm)	**Mean yield per plant* (gm)	*Survivors (of 72 plants)*
Puerto Rico Wonder	11·6	81·2	946	59
California Wonder	8·4	74·9	632	52
C.W./P.R.W. (%)	72	92	67	88
(b) Second trial, 12 June to 18 Oct., 1953 (All plants artificially infected)				
Puerto Rico Wonder	2·17	59·2	128	59
California Wonder	1·35	55·2	74	42
C.W./P.R.W. (%)	62	93	58	71

* Mean calculated from the initial number of plants

VIRUS-LIKE SYMPTOMS DUE TO MITES

The condition which Ferguson[7] attributed to a virus and called ' tomato bronze-leaf ' frequently affects tomato plants grown in greenhouses for experimental purposes. Sometimes tomatoes growing in sheltered spots, such as under the eaves of houses, are attacked, but the disease has only been seen occasionally in the open.

The first symptom is a check to growth, accompanied by discolouration and twisting of the terminal leaves. The leaflets become thickened and their margins may curl downwards, tending to be rather glaucous above and glossy below. Later, the terminal shoots become spindly and the leaflets much reduced in size, while stems, petioles and leaflets develop a dull bronze colour. Proliferating side shoots may be attacked in turn. Frequently, the tips wither and the whole plant may be killed. Plants that survive are normally barren and worthless, though if planted out in the field they may produce healthy side shoots and become productive.

Dusting with sulphur was found to bring about recovery, if carried out soon after the symptoms appeared. This is not surprising as the disease appears to be caused by mites, just discernible on affected shoots with the naked eye and readily visible under a microscope or hand-lens. Supposed transmission of the disease to tomato and other Solanaceae by mechanical inoculation or grafting, reported by Ferguson[7], was presumably due to contamination of the test plants or grafting material with these mites, which readily enter screened cages and greenhouses.

Often, during virus investigations in the greenhouse, other experimental Solanaceae also showed symptoms associated with mite infestation and amenable to dusting with sulphur. Though no attempt was made to identify the mites concerned, spread from one host species to another seemed to occur. Potato developed symptoms similar to those described on tomato, with frequent death of the growing points. The leaves of affected *Nicotiana* spp. and eggplants became curled downwards at the margins, discoloured, and usually glossy beneath. Peppers (*Capsicum annuum*) were severely attacked, so that growth was sometimes completely arrested; the leaves became

discoloured, reduced in size (often almost scale-like), thickened, and usually curled downwards at the margins. The midribs of such leaves were often wavy in the plane of the lamina. These symptoms occasionally occur on peppers in the field.

J. W. L. Peiris[30] reported mite-induced diseases of tomato and pepper in Ceylon that closely resemble the ones described above, although more widespread and serious in the field. Symptoms associated with mites on potato, tobacco, *Physalis peruviana* L., and certain plants outside the Solanaceae were also recorded; mites transferred from pepper or cowpea produced symptoms on tomato identical with those occurring on it naturally. Peiris cited accounts of similar diseases affecting various Solanaceae in Formosa (tobacco), Hawaii (potato), India (pepper, potato) and New York State (potato, pepper, tomato, *Physalis* spp., *etc*). The disease in New York State was attributed to mites of the genus *Tarsonemus*[31]. Riollano, Adsuar and Rodriguez[16] recorded a mite-induced disease of peppers in Puerto Rico, which they attributed to *T. latus* Bank. The symptoms appear to be the same as those on peppers in Trinidad.

SUMMARY

Four sap-transmissible viruses have been isolated from cultivated Solanaceae in Trinidad: tobacco mosaic virus, from tobacco, tomato and sweet pepper; cucumber mosaic virus, from tobacco and petunia; pepper vein-banding virus (probably related to a pepper mosaic virus in Puerto Rico) from peppers and tobacco; eggplant mosaic virus (possibly related to tobacco ring-spot virus) from eggplant and tomato. Only cucumber mosaic virus was found naturally infecting hosts outside the Solanaceae.

In laboratory tests, tobacco and cucumber mosaic viruses gave diagnostic reactions in various hosts belonging to the Solanaceae and other families. Pepper vein-banding virus caused leaf-crinkling and vein-banding in *Physalis floridana*, petunia, various *Nicotiana* spp. and most peppers; the Large Bell Hot pepper was killed; tomato and eggplant proved immune. Eggplant mosaic virus produced mosaic, ring-spotting, or both, on different solanaceous species. It also gave local and systemic ring-spotting on *Chenopodium hybridum* and necrotic local lesions on the primary leaves of cowpea (var. Black-eye); cucumber proved a symptomless carrier.

Tomato twisted-leaf virus, which resembles a Brazilian virus thought to be a strain of sugar beet curly-top, is very common in tomato, causing stunting, leaf-curling and chlorosis. It is not sap-transmissible, but was readily transmitted by grafting to several tomato varieties, and hybrids between tomato and *Lycopersicon pimpinellifolium*; no other hosts are known with certainty.

Aphis gossypii transmits cucumber mosaic and pepper vein-banding but not eggplant mosaic, of which *Epitrix* sp. is an occasional vector. Tobacco mosaic, as elsewhere, probably has no regular insect vectors in Trinidad. Tomato twisted-leaf obviously has efficient vectors, but they are at present unknown.

In Trinidad, tobacco mosaic virus has only rarely caused appreciable losses, when infecting tobacco or sweet pepper. Like cucumber mosaic virus, it might become more troublesome should tobacco growing be

expanded. Measures for the prevention and control of the two viruses are briefly discussed; *Commelina* spp., and probably certain other wild plants, are reservoir hosts of cucumber mosaic virus. Eggplant mosaic virus is of no economic importance at present; although it substantially reduces the yield of tomato plants, natural infections in this host are too rare to be of any account. Pepper vein-banding virus was shown to reduce the yield of sweet pepper, but this is not an important crop. Mild leaf symptoms in Puerto Rico Wonder are associated with resistance to infection, and in yield trials this proved superior to the Fordhook and California Wonder varieties. Tomato twisted-leaf seems a serious disease, worthy of further study.

Certain virus-like symptoms occurring in tomatoes and peppers, normally only under sheltered conditions, are associated with mites. Other Solanaceae became similarly infested from time to time in the experimental greenhouse. The condition can be controlled by dusting with sulphur.

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Germination of Oil Palm Seeds

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HISTORY AND PRINCIPLES

It is not surprising that, from the early days of the cultivation of oil palms as a plantation industry, efforts have been made to improve both the speed and the percentage of germination of the seed. Fresh seed, from which the oily pericarp has been removed, germinates slowly when planted in nursery beds composed of ordinary soil. Approximately 30 per cent germination is obtained within a period of six months, 50 per cent within nine, and 85 per cent within 12 months[1,2]. The germination of whole fruits was found to be still slower and less complete[3]. This slow and uncertain germination is a serious drawback to the plantation industry in general, but particularly in Africa, where the periods when climatic conditions suitable for planting-out in the field are restricted.

As a consequence of the work in 1936 of A. Beirnaert[4] and others the classical technique of germinating oil palm seeds in open sandbeds was gradually abandoned. P. Henry[5] gives a review of the methods used to accelerate the process and to improve the percentage of germination before that time, and further details may be found in the publication of Beirnaert[4] and the textbooks.

The older methods, consisting of various treatments applied to the nuts before planting out, for example soaking in water, or in diluted solutions of acids, alkali or salts, had little effect, and never found general application in plantation practice on account of their high cost and unreliability. Fermenting the seeds by placing them in pits or boxes with cattle manure or vegetable matter gave results which compare favourably with those of the present methods[2]. The same is true for germination beds covered with a glass frame[6].

The new methods are based on the principles derived from previous experience that the speed of germination is improved by rather high temperatures, good aeration and adequate moisture conditions. An excellent review was recently given by R. Galt[7]. The basic difference from the older methods lies in the fact that the seed is germinated prior to planting out in seedbeds, and no longer germinates in the seedbed itself. The great advantage of this technique is evident. The stand in the seedbeds becomes much more regular, enabling the removal of whole batches of seedlings at the same time for planting out in nurseries, whilst seedlings ready for planting out in the old type germination beds were scattered, and had to be removed one by one. In addition, the time required to produce a seedling ready for planting out from germinated seed, is much shorter than that from ungerminated seed, so that the risk of damage from pests and diseases in the seedbeds is considerably reduced.

RÔLE OF THE PERICARP

Although the original reason for removal of the pericarp was to improve access of water to the germ[8], additional advantages are greater facilities for storing and transport. Little or no attention has been paid to the possible rôle of the pericarp, as such, in the germination mechanism. It is common experience that oil palm seeds, from which the oily pericarp has been removed, remain dormant for periods varying between three weeks and several months after placing under optimal germination conditions. This period, although showing considerable differences for seeds of various origin, and probably determined by the internal physiological or genetical condition of the seed, is little affected by treatments applied to the nut with a view to improving the speed of germination[5].

Experiment Yal 4e was designed to obtain information concerning the rôle of the pericarp in the germination process by studying the effect of removing the pericarp by hand after various periods of time from fruit kept under the same conditions of temperature and humidity before and after the removal of the pericarp. The experiment included the following comparisons:

1. Pericarp removed immediately
2. Pericarp removed after three days
3. Pericarp removed after one week
4. Pericarp removed after two weeks
5. Pericarp removed after three weeks
6. Pericarp removed after four weeks
7. Pericarp removed after five weeks
8. Pericarp removed after six weeks

The results are shown in *Figure 1.*

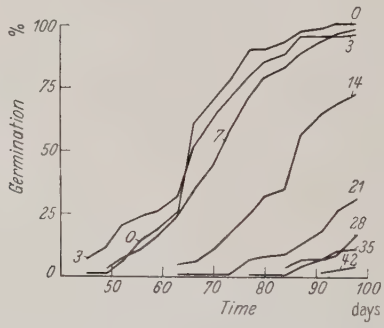

Figure 1. Yal 4e. Cumulative germination of fruits from which the pericarp was removed after various periods of time

From the results it would appear that in ripe fruit, freshly detached from the bunch, the biochemical processes occurring in the pericarp during the first three days seem to increase slightly the initial speed of germination, without noticeably affecting the final percentage of germination. After this short period the pericarp retards germination only slightly during the

first seven days, and without affecting the final percentage of germination, but considerably more when it is retained for a fortnight or longer. The germinative power is only decreased, however, if the pericarp is retained for more than a fortnight.

TREATMENTS APPLIED TO THE NUTS

Henry[5] has drawn attention to the observation that the germination process of oil palm seeds shows two distinct periods. During the first period, which is practically constant for a given batch of seed, and independent of the treatments applied to the nuts and the germination conditions, little or no germination takes place. It was shown previously that the length of this period is increased if the nuts are protected by the oily pericarp for two weeks or longer.

Former efforts to increase the speed of germination during the second period by means of treatments applied to the nuts prior to planting out in germination beds, were not very successful and often resulted in a retardation rather than an acceleration of the germination[4]. A. KORTLEVE[9], however, has reported positive results obtained by immersing five day old seed for two days only in 1 per cent hydrochloric acid, followed by washing in water for a similar period, before planting in sandbeds. In the light of the above experiment on the rôle of the pericarp, the experiments of Kortleve are of particular interest. It seems unlikely that treatments applied to the nuts, prior to planting out, would have any effect on freshly harvested seed. The above considerations may partly explain the failure to obtain positive effects from treatments applied to the nuts in earlier experiments, and would suggest that they only have a chance of success, when applied to at least five day old seed.

One of the germination experiments (Yal 4a) included a comparison between the following treatments applied to the nuts prior to being placed in the germinator: (I) Standard treatment (*i.e.* seed mixed with equal volume of coarsely ground charcoal without pre-treatment); (II) Seed soaked in ordinary water at room temperature during four hours per day until the kernels ceased to rattle, which was the case after four days; (III) Shells removed by carefully cracking the nuts. The object of the experiment was to investigate whether the germination of seed, stored for a period of two months without special precautions, could be accelerated by improving the access of water to the germ. This was the object of the majority of the treatments applied to nuts in previous experiments.

The results are summarized in *Figure 2*. It appears that none of the treatments applied resulted in a shortening of the period of dormancy. No germination occurred during the first 25 days after placing in the incubator. From this it may be concluded that the release of the germination mechanism is not stimulated by a better access of water to the germ.

It is interesting to note, however, that the percentage of soaked nuts (II) to germinate was slightly better during the first weeks after germination started, but this difference disappeared, and even became slightly negative, in the following weeks. The percentage of cracked nuts (III) to germinate was somewhat low in the beginning, but considerably better after the 45th day.

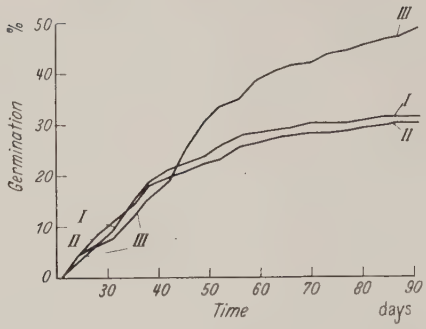

Figure 2. Yal 4a. Cumulative percentage germination after various periods of time for three different treatments applied to the nuts (I, II and III)

Soaking the nuts, therefore, would appear to affect only the initial speed of germination, which advantage is subsequently lost. Removal of the shell, however, results in a considerable increase in the speed of germination compared with the standard treatment. A possible explanation for these seemingly contradictory results is that a short period with excess of water in the vicinity of the germ is beneficial to the seeds, whose germination mechanism was released shortly after the initiation of the germination process, but that the seeds whose germination mechanism is released later cannot benefit from this advantage, because in the intervening time the moisture conditions in the interior of the shell have become the same as those of the nuts receiving the standard treatment. In the light of the above considerations it may be readily understood that soaking is beneficial if a batch of seed has a high potential germination energy and a short period of after-ripening, but of little or no effect if this is not the case.

The quicker germination of the kernels may be explained by improved access of water to the germ and better aeration compared with the standard treatment.

To assist in drawing a practical conclusion from this experiment, the germinated and non-germinated nuts and kernels of each treatment were planted out separately in sandbeds. *Table 1* gives a summary of the results obtained.

Table 1. Yal 4a. Effect of treatments applied to the nuts on the growth in the seedbeds

	Per cent of original number of nuts		
	Standard (I)	*Soaked (II)*	*Cracked (III)*
(*a*) *Germinated in incubator and planted out in sandbeds*	31·2	30·0	48·5
(*b*) *Ungerminated and placed in sandbeds* ..	68·9	70·0	61·9*
(*c*) *Seedlings obtained from (a)*	30·2	25·9	32·5
(*d*) *Seedlings obtained from (b)*	18·6	15·1	7·4
(*e*) *Total number of seedlings remaining from (a)+(b)*	48·8	41·0	39·9
(*f*) *Maximum number of seedlings obtainable after splitting of doubles*	55·8	46·9	39·9

* 4·0 per cent was lost through rotting during the germination

It appears that the advantage of quicker germination by removing the shells is completely lost after planting out in sandbeds, receiving standard treatment of watering and insect control. It would seem that seedlings, originating from germinated kernels, (*III*), and soaked seeds, (*II*), are less vigorous than those grown from seed, (*I*), which had received the standard treatment. The losses in seedlings which received the standard treatment were very small. Another striking phenomenon is that, from the seeds which failed to germinate in the incubator, seed receiving the standard treatment and the soaked seed still showed a rather surprising germinative power, while only a small number of the kernels germinated in the sandbeds.

Fifty-two plants of each of the series (*I*) and (*III*) were planted out in nursery beds under rather dry weather conditions. A fortnight after transplanting, the plants originating from the standard treatment showed 12, and those from the kernels 38 losses, illustrating again the poor vigour of seedlings originating from germinated kernels.

The poor vigour of seedlings originating from germinated kernels is probably due to insufficient protection of the haustorium, which increases in size with the age of the plant, and damage to the kernel by pests and diseases. That of the seedlings originating from soaked seed is more difficult to understand, and must be caused by initial damage to the germ by prolonged anaerobic conditions inside the shell.

From the results of this experiment the conclusion may be drawn that soaking the nuts and removal of the shells are of no practical interest in improving the germination of oil palm seeds.

GERMINATION MEDIUM

The evidence presented by Beirnaert[4] leaves little doubt that wood charcoal is an excellent germination medium for oil palm seeds. Henry[5] recommends four parts coarse river sand, two parts charcoal and three parts *terre franche*, but it should be borne in mind that the germination percentages obtainable in practice with charcoal within a period of three to four months are considerably higher than those reported by Henry in glasshouses with his improved methods[10].

In experiment Yal 4b the following germination media were compared: (i) Charcoal, (ii) Sand, (iii) Sawdust, (iv) Pericarp fibre. The average percentages of germination obtained after six months are shown in *Table 2*.

Table 2. Cumulative percentage germination in various media after six months

Medium	*Per cent*
(i) *Charcoal*	80
(ii) *Sand*	2
(iii) *Sawdust*	1
(iv) *Pericarp fibre* ..	2

There is not the slightest doubt that charcoal is an outstanding germination medium compared with sand, sawdust and pericarp fibre under identical conditions of temperature, humidity and aeration in an incubator. It is not easy to understand, however, why the other media are such a complete

failure. Aeration and moisture conditions may be better in charcoal, but cannot explain the practical absence of germination in the other media. Moreover, seeds germinate in open sandbeds and in rotten bunches, where the nut is still surrounded by pericarp fibres. A possible explanation is that one or more substances, secreted by the seed itself in heavy concentration, prevent germination. Excessive concentrations of similar substances are less likely to occur in open, well-drained seedbeds and even in rotten bunches than in germination boxes, where relatively large quantities of seed are contained in a small space. This would also explain the outstanding properties of charcoal as a germination medium, as charcoal is known to adsorb a wide range of organic and inorganic substances, so decreasing their activity. An additional possibility in the case of pericarp fibre and sawdust is that the medium itself contains or produces substances, which prevent germination.

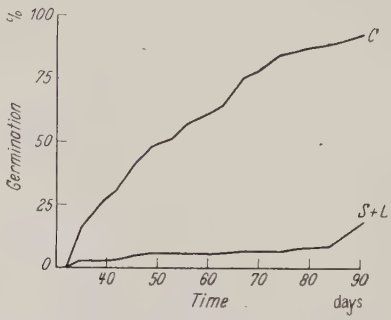

Figure 3. Yal 4c. Cumulative percentage germination after various periods of time in wood charcoal (C) and in sand with 1 per cent hydrated lime (S+L)

One of the substances secreted by the seed is carbon dioxide, which may easily accumulate in the seed containers. High concentrations of carbon dioxide are known to prevent the germination of many seeds, and this condition may have obtained for the above seeds in sand, pericarp fibre and sawdust (Yal 4b). An attempt was made, therefore, to germinate oil palm seed in sand, to which 1 per cent hydrated lime was added to absorb excess carbon dioxide (Yal 4c). The results obtained are shown in *Figure 3*. It appears that the speed of germination of oil palm seeds under identical conditions of temperature and humidity is much greater in charcoal than in sand plus hydrated lime. It will be noted, however, that the germinative power of the seed in the sand is not lost.

TEMPERATURE

General experience would seem to suggest that the optimum temperature for germinating oil palm seeds is in the vicinity of 37°C, but the literature on this subject is not very conclusive. The experiments of T. Hinrichs[11] and Beirnaert[4] indicated that the optimum temperature is between 34° and 37°C, but the seed referred to was treated with water at different temperatures during seven to fourteen days for seven to ten hours per day, after which

it was planted out in sandbeds. It is interesting to note that temperatures of the water over 40°C cause a considerable decrease in the percentage germination after six, seven and twelve months. The germination percentages obtained with the best treatments in these experiments are, however, very low compared with those obtained with present methods. Henry[5] states that the optimum temperature is 38°C. Below 25°C no germination takes place, and the maximum seems to be slightly higher than 40°C. No experiments are quoted, however. Galt[7] indicates 35°C, but the results obtained in Nigeria with a water-heated germinator[12] at this temperature compare unfavourably with the results obtained in plantation practice in the Belgian Congo with the fermentation box[4,10] and with those obtained here in an indirectly heated germination chamber and in biological incubators. This would seem to indicate that a maximum temperature in the vicinity of 35°C during the germination process is too low for optimal results. This is further confirmed by the results obtained in two separate germination experiments in egg-incubators (Yal 4a and 4b). In both experiments with directly comparable treatments the germination after three months (91 days) was 31 per cent at 38°C against none at 35°C. The type of the seed used in these experiments was different, however, and the results, therefore, not strictly comparable

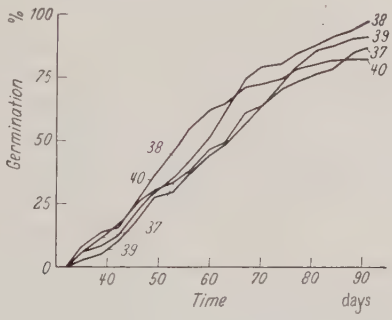

Figure 4. Yal 4c. Cumulative percentage germination after various periods of time at 37°, 38°, 39° and 40°C

To obtain more precise information concerning the optimum temperature, oil palm seeds mixed with equal quantities of wood charcoal, which contained approximately 40 per cent moisture after each twice-weekly adjustment, were placed in biological incubators maintained at 37°, 38°, 39° and 40°C respectively (Yal 4c). The percentage germinations obtained after various periods of time are shown in *Figure 4*. From this it appears that the effect of temperatures between 37° and 40°C is not very different. The germination at 40°C is somewhat quicker in the beginning, but eventually, after 13 weeks, the highest percentage was obtained in the incubator maintained at 38°C, immediately followed by that at 39°C. Both 37°C and 40°C gave slightly lower percentages. This result would seem to confirm that the optimum temperature of germination for oil palm seeds is in the vicinity of 38°C[5], but also indicates that temperatures as high as 40°C and as low as 37°C still give excellent results.

The beneficial effect of a periodical cooling of the seed was shown by Henry[5]. Although the germination in these experiments, even with cooling, is not quicker than that obtained in germination boxes[10], the effect of cooling is striking. The best results were obtained when the seed was removed from the thermostatic chamber for periods of 24 hours once every fortnight, after being left undisturbed during the first two months.

In order to determine whether the beneficial effect of a periodical cooling also holds true for oil palm seeds grown under Congo conditions of soil and climate, this procedure was compared with the standard treatment (seed permanently kept at the same temperature) in a number of experiments (Yal 4a, 4b, 4c).

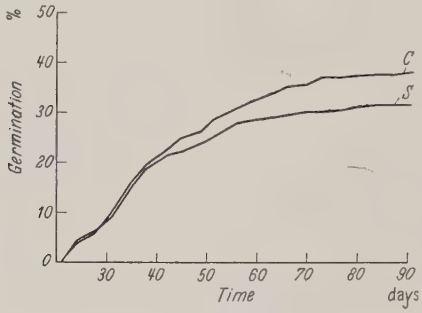

Figure 5. Yal 4a. Cumulative percentage germination after various periods of time, of seed permanently kept in the incubator (S) and seed removed from the incubator for periods of 24 hours once every fortnight, after being left undisturbed for the first 38 days (C)

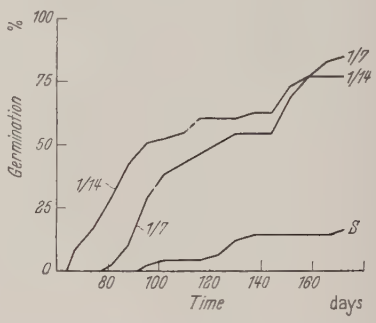

Figure 6. Yal 4b. Cumulative percentage germination after various periods of time, of seed permanently kept in the incubator (S) and seed removed from the incubator for periods of 24 hours once every week (1/7) or once every fortnight (1/14), after being left undisturbed for the first week or fortnight respectively

The first experiment of this series included a comparison between seed receiving the standard treatment and seed removed from the incubator for periods of 24 hours once every fortnight, after being left undisturbed for the first 38 days (apart from regular examinations twice per week after the germination started). The results are shown in *Figure 5*. It appears that periodical cooling has improved the total percentage of germination obtained after three months. The percentages of germination, as such, however, were not very satisfactory, and compare unfavourably with those obtained later within the same period of time in biological incubators. This is probably due to insufficient aeration in the egg incubators.

Experiment Yal 4b included comparisons between the following treatments:

(I) Standard treatment.

(II) As (I), but removed from the germinator for periods of 24 hours once every week.

(III) As (I), but removed from the germinator for periods of 24 hours once every fortnight.

The temperature of the incubator was maintained at 35°C in this experiment, which partly explains the slow and unsatisfactory germination of the seed

receiving the treatment (I). On the other hand, the seed used in this experiment was of the Dura type, which is known to germinate quicker than Tenera type seed under the same conditions of temperature and humidity[4,5]. The results are shown in *Figure 6*. Here, the beneficial effect of periodic cooling is still more pronounced, as the seed receiving the standard treatment germinated very slowly at this low temperature. Contrary to the experience of French workers[5] cooling appears to increase the speed of germination from the beginning, and not only after two months. Cooling once every fortnight is initially better than once every week, but the difference disappears after approximately five months. Although the speed of germination was not very satisfactory, probably due to too low a temperature, the beneficial effect of cooling is very striking.

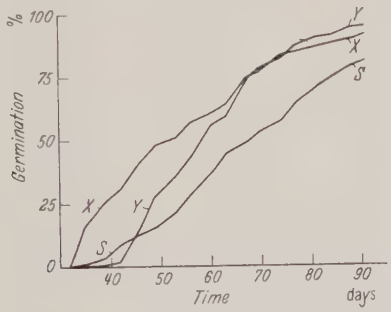

Figure 7. Yal 4c. Cumulative percentage germination of seed permanently kept in the incubator (S), removed from the incubator for periods of 24 hours once every fortnight (X) after being left undisturbed for the first four weeks, and contained in a perforated container (Y)

A third experiment (Yal 4c) again comprised a comparison between seed receiving the standard treatment and seed removed from the incubators for periods of 24 hours once every fortnight. Here, as appears from the results shown in *Figure 7*, cooling affected mainly the percentage of germination per unit of time between day 32 and day 49. After this period the effect was negligible, but the initial advantage was maintained during the whole of the subsequent germination process. In this experiment even the seed receiving the standard treatment gave very satisfactory results, 81·5 per cent germination being obtained after 91 days, but the periodically cooled seed had reached the same percentage 17 days earlier.

The results of the above series of experiments confirm that the optimum temperature lies in the vicinity of 38°C, and that periodical cooling to room temperature (25°C) for periods of 24 hours once every fortnight is beneficial. They seem to contradict, however, Henry's statement[5] that cooling only becomes effective after the initiation of the germination process, as, in the second experiment, the series removed from the incubator for periods of 24 hours once every fortnight germinated approximately four weeks earlier than the series permanently kept in the incubator. This would seem to indicate that fluctuating temperatures as such, or at least conditions induced

by the periodical removal of the seed from the incubator, not only affect the speed of germination after the beginning of the germination process, but also affect the beginning of the germination process itself. It would further appear that there is an optimum frequency of cooling with respect to the shortening of the period of non-germination, as the seeds removed from the germinator once every week germinated later than those removed once every fortnight, although still a fortnight earlier than those kept permanently in the incubator. It is interesting to note, however, that the length of the period of non-germination is not affected by periodical cooling, provided the temperature of the incubators is between 37° and 40°C, but only in the incubator kept at a lower temperature (35°C). This would serve to explain why Henry found that the period of non-germination is not affected by fluctuating temperatures, and indicate that this effect of periodical cooling is of no practical importance if the temperature is kept at a sufficiently high level.

Henry[5] has presented evidence to suggest that the beneficial effect of a periodical removal of the seed from the germinator is due to the decrease in temperature, and not to changes in other conditions affecting germination as a consequence of this removal. Although his evidence does not provide an absolute proof, it would seem fairly safe to assume that, if changes in other conditions are involved, they must be closely related to changes in temperature. One of the possible factors mentioned by Henry is the complex moisture–aeration conditions, but he considers that improved aeration of the seed in the containers periodically removed from the germinator, as a consequence of a higher evaporation, plays no important role. In experiment Yal 4b, the differences in evaporation between the containers permanently kept in the incubators and those periodically removed for periods of 24 hours are negligible, which also tends to suggest that differences in moisture conditions are not likely to interfere to any large extent. This is not necessarily the case for aeration, as the change in temperature is bound to induce some circulation between the warm air in the container and the surrounding air, after removal from the incubator. It should be borne in mind, however, that, in the Yal experiments, this improved air circulation is not likely to have much effect after the initiation of the germination, as the temperature of the containers 'permanently' kept in the incubators is essentially the same as that of the containers, periodically taken out of the germinator after each removal of germinated seed.

One of the experiments (Yal 4c) provides evidence, which, although not entirely conclusive, tends to suggest that better aeration of the seed improves germination, but only if it is, at the same time, submitted to temperature changes. This experiment included a treatment, in which the seed was placed in perforated containers instead of glass beakers. The perforated containers were not removed from the incubators before the initiation of germination (35 days), but as the germination in these containers was slow compared with that in the beakers, which had been removed for the first time for 24 hours on the 28th day, it was decided to remove them as well. This was done for the first time on the 42nd day. From the results shown in *Figure 7* it appears that the speed of germination immediately increased after this first removal, and that eventually, after 67 days, the percentage of

germination, obtained in the perforated containers, was the same as that in the beakers periodically removed. Even after this period, the percentage germination per unit of time in the perforated containers remains slightly higher than that in the beakers. It will be shown in the following section that higher evaporation (approximately four times) per unit of time in the perforated containers compared with the beakers is not the cause of the increased speed of germination. It must, therefore, be concluded that although better aeration of the seed improves the speed of germination, this improvement does not explain the effect of a periodical decrease in temperature.

MOISTURE CONDITIONS

It is evident that, in a rather fine germination medium such as wood charcoal, moisture content and aeration are bound to be closely related. The aeration may be improved by lowering the moisture content and *vice versa*, and it seems likely that periodical fluctuations in the moisture content will improve the circulation of the air in the charcoal. On the other hand, it is questionable whether better circulation of the surrounding air in the incubators is very important. This would serve to explain why germination in the perforated containers was not better than that in the beakers, permanently kept in the incubators, before the former were removed for periods of 24 hours once every fortnight (see *Figure 7*).

To obtain more precise information concerning the influence of the moisture content and its fluctuations per period of three to four days, an experiment was designed to compare the following treatment combinations (Yal 4e):

A. Moisture content of the atmosphere—1. Relative humidity 100 per cent. *2.* Relative humidity 50 per cent.

B. Initial moisture content of the charcoal—1. 24 per cent. *2.* 36 per cent. *3.* 48 per cent. *4.* 60 per cent.

Table 3. Cumulative percentage germination after various periods of time in relation to the magnitude of the periodical (three to four days) decrease in the moisture content of the charcoal

Time (days)	*Cumulative germination per cent*	
	Slight decrease	*High decrease*
35	0·00	0·25
42	0·75	0·75
49	3·50	3·25
56	10·75	10·25
63	16·75	16·75
70	21·00	19·75
77	37·50	32·75
84	56·00	53·75
91	67·00	67·75
98	77·75	81·50
105	83·75	87·50
112	88·75	90·75

The results are shown in *Table 3*. It appears that the degree of humidity of the air in the incubators had no influence on the germination. This may

seem rather surprising, because the evaporation from the containers in the dry air was considerably higher than that from the containers in the saturated air, as would be expected. Consequently, the fluctuations in the moisture content of the charcoal per period of three to four days, were much greater in the dry air.

The moisture content of the charcoal was adjusted twice per week (hence after three or four days respectively) to the original percentage of the treatment. This represents, therefore, the maximum moisture content in series *B*. Contrary to expectations, it appears that the maximum moisture content of the charcoal has a great influence on the speed of germination, partly by affecting the period of dormancy, but probably without affecting the final percentage of germination (*Figure 8*). The speed of germination increases with increasing moisture content of the charcoal, and the wettest charcoal, which was very nearly saturated to its maximum water capacity, proved to give the best results. A considerable decrease in the speed of germination may be noted if the moisture content falls below 36 per cent.

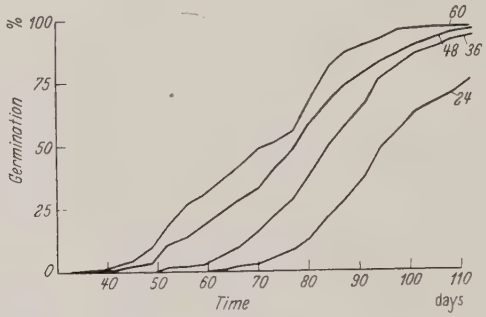

Figure 8. Yal 4e. Cumulative percentage germination after various periods of time in wood charcoal of different moisture content (60, 48, 36 and 24 per cent respectively)

The results of the above experiment would seem to indicate that oil palm seeds are sufficiently protected against considerable fluctuations in the moisture content of the germination medium. The moisture content of the wood charcoal as such, however, plays a very important rôle in the germination process, and the maximum degree of saturation obtained seems to determine the speed of germination, independently of the greater or smaller fluctuations during periods of three or four days. The speed of germination is especially decreased, if the moisture content of the charcoal is maintained below 36 per cent.

As the speed of germination of oil palm seeds is independent of the periodical fluctuations in the moisture content of the charcoal, it is evident that the latter cannot explain the beneficial effect of periodical cooling of the seed, or that of the conditions obtained in a perforated container. It must, therefore, be concluded that the beneficial effect of periodical cooling is due mainly to the decrease in temperature. Improved aeration of the seed, which is especially obtained in the perforated containers, only seems to affect the speed of germination if the containers are periodically removed from the germinators and placed in contact with fresh cold air.

CONCLUSIONS

The period of time, after which the pericarp is removed from ripe fruit freshly detached from the bunch, has a great influence on the speed, and probably also on the final percentage of germination. The speed of germination is slightly increased, although only initially, by retaining the pericarp for a period of three days, but the speed is greatly decreased, if this period lasts longer than a week. The final percentage of germination is not affected if the pericarp is removed within a week, but seems to decrease if this is done after two or more weeks.

The release of the germination mechanism is not stimulated by a better access of water to the germ, as neither soaking of the seed nor removal of the shells results in a shortening of the period of dormancy. Soaking only slightly affects the initial speed of germination, but removal of the shells causes a considerable increase. The seedlings originating from both soaked seeds and germinated kernels, especially from the latter, are less vigorous than those obtained from seeds receiving the standard treatment. These treatments, therefore, are of no practical interest in improving the germination of oil palm seeds.

Wood charcoal is an outstanding germination medium for oil palm seeds compared with sawdust, sand and pericarp fibre. This is probably due to its high capacity to absorb a wide range of inorganic and organic substances, which may be produced by the seed itself during the germination process and which in excessive concentrations prevent the release of the germination mechanism.

The optimum temperature for germinating oil palm seeds seems to be in the vicinity of 38°C, but only temperatures below 37°C are likely to retard considerably the germination, and those above 40°C to decrease the germinative power. The speed of germination is greatly improved by a periodical decrease in temperature. Periodical cooling only affects the length of the period of dormancy, if the temperature of the incubators is below 37°C. The effect of fluctuating temperatures is probably a straight temperature effect, or at least due to changes in conditions, which are closely related to the change in temperature.

The speed of germination is improved by a better aeration of the seed, but only if it is submitted at the same time to fluctuating temperatures.

The speed of germination is not affected by periodical fluctuations in the moisture content of the charcoal. The moisture content of the charcoal as such, however, has a great influence on the germination. The speed of germination increases with increasing moisture content, the best results being obtained in charcoal which is very nearly saturated to its maximum water capacity.

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APPENDIX

Germination Experiments

The equipment used for the germination experiments consisted of a Hearson's oil-heated egg incubator Model Oil (Yal 4a and 4b) and four Hearson's oil-heated biological incubators Type 'B', No. A1010 (Yal 4c, 4d and 4e). For the experiments in the egg incubator, the seed was placed in 16 open zinc containers, made to fit into the drawer, and measuring approximately $12{\cdot}5 \times 12{\cdot}5 \times 7{\cdot}5$ cm. For the biological incubators the seed was contained in 600 ml glass beakers, with the exception of one series in Yal 4c. Here the seed was placed in perforated metal containers of the same dimensions as the glass beakers. The temperature of both the egg and biological incubators showed fluctuations of less than 0·5°C from the desired temperatures.

Yal 4a. Influence of treatment applied to the nuts before and after placing in the incubator—Started 5 November, 1951, concluded 4 February, 1952.

Treatments: (i) Standard method (*i.e.* no treatment). (ii) Seed soaked in tapwater at room temperature (25°C) for a period of four hours per day until the kernel ceased to rattle, which was the case after four days. (iii) Shells removed previous to putting the seed into the germinator. (iv) Standard treatment for the first two months; then seed taken out of the germinator for a period of 24 hours every fortnight.

Design: One 4×4 Latin square, 97 seeds per container.

Layout: Each of the sixteen groups of 97 seeds (or 111 kernels) was mixed with an equal volume of ground wood charcoal and moistened. The temperature of the incubator was kept at approximately 38°C, and the air in the incubator was constantly saturated. The germinated seeds were removed twice per week and planted out in sandbeds.

Yal 4b. Influence of the germination medium and cooling of the seed before and after placing in the germinator—Started 2 March, 1952, discontinued 27 August, 1952; Dura type seed from one open-pollinated bunch.

Treatments: (i) Standard method. (ii) Seed cooled 24 hours in a refrigerator at 3°C before being placed in the germinator. (iii) Seed taken

out of the germinator for a period of 24 hours every week. (iv) Seed taken out of the germinator for a period of 24 hours every fortnight.

Germination medium: (a) Wood charcoal. (b) Pericarp fibre. (c) Sand. (d) Sawdust.

Design: One 4×4 Graeco-Latin Square, 50 seeds per container.

Layout: Each of the 16 lots of 50 seeds was mixed with an equal volume of ground wood charcoal, pericarp fibre, sand or sawdust, and moistened to approximately 50 per cent of the water capacity of the medium. The temperature of the incubator was maintained at 35°C. The germinated seeds were removed twice per week and planted out in sandbeds.

Yal 4c. Influence of the temperature of the incubator, the germination medium, periodical cooling and improved aeration of the seed—Started 22 January, 1954, discontinued 13 weeks later; seed from open-pollinated Dura trees.

Treatments: *A. Temperature.* (i) 37°C, (ii) 38°C, (iii) 39°C, (iv) 40°C.

B. Container and medium. (1) Beaker with moist charcoal. (2) Beaker with moist charcoal, removed from the incubator for periods of 24 hours once every fortnight. (3) Beaker with sand, mixed with 1 per cent hydrated lime and moistened to 50 per cent of water capacity. (4) Perforated metal container with moist charcoal.

Design: Each of the treatments of series *A* was allocated to an incubator, which was kept constant at the indicated temperature and a relative humidity of 100 per cent. Each incubator included all the treatments of series *B*. The number of seeds per container amounted to 50.

Layout: Each of the 16 lots of 50 seeds was mixed with an equal volume of ground wood charcoal or sand and moistened to approximately 50 per cent of the water capacity of the medium. A large Petri dish filled with water in order to assure a saturated atmosphere, and a smaller one, filled with hydrated lime to absorb excess carbon dioxide, were placed in each incubator. Four weeks after placing in the incubators the containers allocated to the treatments *B* (2) were removed for the first time for a period of 24 hours. Two weeks later, the containers allocated to the treatments *B* (3) and *B* (4) were removed for similar periods.

Yal 4d. Influence of the moisture content of the air in the incubator and of the charcoal—Started 30 April, 1954, discontinued 16 weeks later; seed from open-pollinated Dura trees.

Treatments: *A. Moisture content of the atmosphere.* (1) Relative humidity 100 per cent. (2) Relative humidity 50 per cent.

B. Initial moisture content of the charcoal. (1) 24 per cent. (2) 36 per cent. (3) 48 per cent. (4) 60 per cent.

Design: Two replications for the treatments *A*, four for the treatments *B*. Fifty seeds per container.

Layout: Each of the 16 lots of 50 seeds was mixed with an equal volume of ground wood charcoal, previously moistened to the different water contents (on air-dry charcoal), and placed in 600 ml beakers. In two incubators, the air was constantly kept saturated by means of a large Petri dish filled with water. In the other two incubators the air was only moistened

by the water evaporating from the seed-containers, and moreover dried by means of a Petri dish filled with glycerol, which was regularly renewed. The temperature of the incubators was kept at 38°C, and the seed removed from the incubators for periods of 24 hours once every fortnight.

Yal 4e. Influence of the pericarp—Started 30 April, 1954, discontinued 15 weeks later; seed from open-pollinated Dura trees.

Treatments: (1) Pericarp removed immediately. (2) Pericarp removed after three days. (3) Pericarp removed after one week. (4) Pericarp removed after two weeks. (5) Pericarp removed after three weeks. (6) Pericarp removed after four weeks. (7) Pericarp removed after five weeks. (8) Pericarp removed after six weeks.

Design: Two replications for each of the treatments.

Layout: Ripe Dura fruits, freshly detached from the fruit bunches, were divided into 16 lots of 50 fruits. From two lots the pericarp was removed immediately, from two lots three days later, and so on. After removal of the pericarp the seed was mixed with an equal volume of wood charcoal. Both whole fruits and cleaned nuts were kept in an incubator (temperature 38°C, saturated atmosphere), and cooled for periods of 24 hours once every fortnight to room temperature.

Fertilizer Experiments with Yams in Eastern Nigeria 1947–51

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Yams are grown in all five provinces making up the Eastern Region of Nigeria, where the crop constitutes an important part of the local diet. In certain areas there is a considerable local export to other parts of the region, with a limited amount sent to Fernando Po.

In the 1930's considerable work was carried out on the effect of lime on the yield of the yam crop, in what were then known as the eastern provinces of Nigeria, with particular emphasis on Onitsha and Owerri provinces[1,2]. A programme of fertilizer experiments about to be completed in 1940, had to be abandoned due to the outbreak of the war. In 1946 when limited supplies of fertilizers became available a series of simple randomized block experiments was laid down. In 1948, 3^3 NPK factorial layouts were introduced and became the standard layout for fertilizer experiments in the region.

This experimental programme in connection with the fertilizer requirements for the yam crop, which is grown by peasant farmers of different native tribes each with their own cultural methods, presented a number of problems. The more important of these were (*a*) Supervision, (*b*) Sites, (*c*) Cultural practices and (*d*) Soils.

Supervision

The agricultural chemist who was initially responsible for the design, rates of application and statistical analysis of the experiments, was stationed at Ibadan in western Nigeria, some 300 miles from the Eastern Region boundary. Thus the supervision of each experiment, from the selection and acquisition of the site to the final harvest and disposal of the crop, became the duty of the provincial agricultural officer, aided by his African staff.

The provincial agricultural officer had a large area to cover, and together with his normal duties, could not make regular visits to the experiments for the purposes of observations, *etc*. The normal system of a single log book, where all operations and observations were recorded, which had proved satisfactory on Government farms, soon became impossible on these outstation experiments, for often the Agricultural Officer and the Agricultural Chemist were not well informed about the results. The final solution was the introduction of triplicate note books; after each entry a copy was sent to the agricultural officer and to the agricultural chemist at their respective headquarters. The agricultural assistants were given instructions for grading for growth, colour and vigour. The results were submitted fortnightly together with any other observations, such as animal damage, disease, *etc*. This system worked quite well and kept the officers in charge informed and

permitted remedial action, where possible, to be instigated at the earliest possible date. The chemist was able, after 1949, due to better transport facilities, to visit all sites two or three times a year. These visits were usually timed to aid in the selection of the site and later to obtain a first-hand picture of the progress of the experiments. By means of a few visits from the agricultural officer and chemist, together with the regular observation reports, a reasonable degree of supervision was obtained.

Sites

The question of experimental sites was an annual problem. There was only one Government farm in each province; it was therefore necessary to find sites in other areas of the provinces. In a country where the peasant farmer has a small holding, often made up of a number of different areas due to the system of land tenure, it is very difficult to obtain a uniform three-acre piece of land in any particular area[3]. The 3^3 factorial layout required approximately three acres of land, as earlier work had shown that the most suitable plot size for yams was one-tenth of an acre. Land was acquired for the experimental work in a number of ways: (*i*) the land was rented, with the Government supplying all labour so that the crop was also Government property; (*ii*) the Government supplied the planting material and paid for some cultural operations such as harvesting; the farmer then received the crop less the amount of the seed material supplied; (*iii*) the farmer did everything connected with the crop and received a nominal cash sum for co-operation. In connection with sites, it must be recognized that yams require a fertile soil and the farmers usually reserve their best land for the crop, and are therefore very loath to rent the land or do anything that might prejudice their yield. They had no knowledge of the benefits of fertilizer, other than compost, and were very suspicious of its initial introduction.

Cultural practices

All experiments in the region were conducted in accordance with local practice. Local practices varied from province to province and from district to district within provinces. The greatest variations in practice are (*i*) Land preparation, (*ii*) Varieties, (*iii*) Planting material, (*iv*) Intercrops and (*v*) Harvesting.

Land preparation—Throughout the region yams are almost entirely grown on land freshly cleared from bush. This bush will vary in density, type of vegetation (which may be any type of natural vegetation, which is extremely variable, or planted *Acioa barteri*), and the length of time the bush is left fallow[4]. The normal routine is to underbrush the bush as high as one can reach with a cutlass, together with either partial or full felling of the larger trees. This operation is carried out during the dry season and the area is burnt over just before the commencement of the rains. The time and method of burning is an art, for if the burn is too hot there will be poor regeneration of the bush after the cropping cycle; if on the other hand a poor burn occurs, there will not be sufficient ash, which acts as a fertilizer, and considerable labour will be required to clear the area. The land is then hilled or ridged except in a few places where the land is extremely

sandy, *e.g.* Owerri Province, where a shallow hole is scooped out for the planting material. Where ridges are used, they are more or less uniform but the spacing of the sets will vary considerably. In the case of hills there is a very large variation in size, from those planted with a single set to those having eight or ten sets, such as are found in parts of Ogoja Province.

Varieties—There are three main species of yams grown in the region, which in order of importance are the white yam (*Dioscorea rotundata*), the yellow yam (*D. cayenensis*) and the water yam (*D. alata*). There are numerous varieties of each species which are peculiar to particular areas, having been selected for various purposes such as storage, and their suitability for pounding, roasting or boiling. The varieties will differ considerably in size, shape, colour and consistency of flesh and in the date of maturity.

Planting material—The yam is propagated vegetatively by means of sets. The sets will vary from small seed yams to sectional cuts of a mature yam, which may be used alone or in combination with seed yams. Sectional sets are referred to as ' tops ', ' middles ' and ' bottoms ' and vary in size according to the particular farmer. Seed yams and tops have the highest germination and so are preferred, but in some areas middles and bottoms are used to a fair extent, especially when planting material is in short supply. The weight of sets planted will vary from 10 cwt to one ton per acre depending on the size of set and the stand per acre. Close supervision was required at planting time in experimental sites, especially when sectional sets were used and when the planting material came from more than one source, otherwise plot differences would have occurred that bore no relation to the treatments.

Intercrops—In a few places yams are grown as a sole crop, but the vast majority are grown with from one to five intercrops. These intercrops include maize, okra, pumpkin, telfairia and melon. Cassava is almost universally interplanted about July and harvested fifteen to eighteen months later. The yam crop is known as the farmer's or man's crop, while the intercrops are the women's crop. The women plant, harvest and sell their intercrops independently, which makes it extremely difficult to obtain accurate data. In order to obtain uniformity with regard to plant population in each area, local surveys were conducted on five to ten farms to obtain the average stand of such intercrops, which were then evenly spaced throughout each yam plot in the experiment. In addition there is the problem of obtaining data about the telfairia, ' egusi ' (melon) and pumpkin crops, as the leaves of these plants are harvested during the growing season and sold in penny bunches for making soups. Cassava, which is not only an intercrop but also a residual crop, is usually harvested as needed and thus the harvest often extends over a six month period. Intercrops present a difficult problem to the experimenter, especially when the experiment is conducted on a co-operative basis.

Harvesting—The experimenter also faces a problem with the harvesting of the yam crop. In areas where seed yams are used for planting material, the farmer uncovers the tubers before the vine is mature, cuts off the ware yam by means of a cutlass and re-covers the stump upon which the seed yams later develop. The size of the stump will vary according to the harvester and subsequently the size and number of seed yams also varies.

When no seed yam crop is to be taken, the harvest will take place any time after the local yam feast, from the time the vine just starts to wither until after all the vegetative growth has withered. In co-operative experiments difficulties often arise about when the harvest will take place. Occasionally the farmer harvests the crop without informing the agricultural assistant and all the data are lost. In general practice, harvesting is not advised until all vegetative growth is completely withered, for in many cases where yams have been harvested before this stage, the tubers have been observed to have a still actively growing tip. It has been observed that use of fertilizers prolongs the growing period and the crop should be left as long as possible in order to obtain maximum benefit from the fertilizer.

Soils

The Eastern Region of Nigeria has not been systematically soil-surveyed. Dr H. Vine has prepared a provisional soil map of Nigeria and according to it the experiments discussed in this article are situated in three main soil groups[3]. These three groups are similar in that they are all of a light texture, moderately to strongly leached, moderately to strongly acid in reaction, well drained, and respond to applications of lime. They differ in colour, parent material, and the presence and amount of concretionary material.

EXPERIMENTS

The variations in the actual cultivation of yams, coupled with the periodic changes in rates of application of the different fertilizers make it impossible to combine the results of even one small area for greater statistical precision. The experimental data will be presented province by province in the following manner: description of site and layout in year groups, with the yields results in table form, for like areas in their own year group.

Ogoja province

1947—One randomized block experiment of four treatments, (*i*) nil, (*ii*) basal dressing of 10 cwt lime, $1\frac{1}{2}$ cwt superphosphate and $\frac{3}{4}$ cwt of muriate of potash, (*iii*) basal dressing plus $1\frac{1}{2}$ cwt of sulphate of ammonia, (*iv*) basal dressing plus 3 cwt of sulphate of ammonia, replicated four times, was laid down at Ezza to ascertain the effect of nitrogen. The lime was broadcast before hilling, sulphate of ammonia as a top dressing and the superphosphate and muriate of potash applied to the half-made hill.

1948—Two types of factorial design were used in the province in this year, one a 2^4, the treatments of which were made up of sulphate of ammonia (N) at $1\frac{1}{2}$ cwt, superphosphate (P) at $1\frac{1}{2}$ cwt, muriate of potash (K) at $\frac{3}{4}$ cwt and lime at 10 cwt per acre; the other was a 3^3 NPK layout with the first level of application identical to that of the 2^4 and the second level being double the first level. Two replications of the 2^4 layout were sited in the provincial farm at Abakaliki and a single replication at Ezza. Two replications of the 3^3 layout were also sited in the provincial farm and a single replication each at Ake-Eze and Ikwo. The phosphate and potash fertilizers were applied broadcast before hilling or ridging while the sulphate of ammonia was applied as a top dressing in two equal portions, one at 50 per cent germination and the other a month later as a placement dressing.

1949—No experiments were laid down in the province.

1950—A single replication of a 3^3 layout was laid down at Isieke near Abakaliki. The rates of all fertilizing units were lower than in 1948, sulphate of ammonia and superphosphate being applied at 1 and 2 cwt per acre and muriate of potash at ½ and 1 cwt per acre. As a result of placement experiments all fertilizers were applied as a placement dressing at 60 per cent germination[5].

1951—Two 3^3 NPK experiments were laid down, one at Ikuo and the other at Okposi. The rates of application of fertilizer were the same as in 1950 with the exception of superphosphate, which was altered to 1½ cwt and 3 cwt per acre. Both these experiments suffered from adverse weather conditions, a severe drought just after planting, followed in midseason by flood conditions due to exceptionally heavy rainfall. The Ikuo experiment had to be abandoned as a failure; however, by digging drainage channels, the Okposi experiment was not too seriously affected.

The field results of these experiments are presented in *Table 1*, which gives the actual yield for the nil rate and the difference due to treatments under the dressing rates.

Owerri province

1947—Three experiments were set out in the province, one a 3^3 factorial and the other two randomized block layouts to ascertain the effects of potash on the crop. Due to the sites not being uniform as to past cultural history and a tremendous variation in stand, the randomized block layouts had to be discarded. The 3^3 NPK layout was sited on the provincial farm at Umudike near Umuahia using the following levels of application: sulphate of ammonia at ¾ and 1 cwt per acre, superphosphate at 1 and 2 cwt per acre and muriate of potash at ½ and 1 cwt per acre. The phosphate and potash carriers were applied before planting and the nitrogen carrier as a top dressing in two portions as in Ogoja province.

1948—There were seven experiments in the province, consisting of five 3^3 sited at Obohia, Isoba, Aba, Owerri and on the provincial farm at Umudike; and two 2^4 sited at Ihie Ngwa and Amigbo. The first dressing level in both types of experiment was 1½ cwt per acre for both sulphate of ammonia and superphosphate and ¾ cwt per acre for muriate of potash. The second level was double the first level for the 3^3, which in addition had an overall dressing of 10 cwt per acre of lime; this formed the fourth treatment of the 2^4 layouts. The fertilizers were applied in the same manner as in the previous year.

1949—Only one experiment was carried out which was on the provincial farm. It was conducted as in 1948 except that the rate of application was lowered to 1 cwt and 2 cwt per acre for sulphate of ammonia.

1950—Only two experiments were laid down, one at Isoba and the other at Obohia. They differed from the previous year's experiment only in the method of application, which was placement of all fertilizers at 60 per cent germination.

The yields of the Owerri province experiments are given in *Table 2* in the same manner as the Ogoja province results.

Table 1. Ogoja province, yam fertilizer effects

Year	Place	Expt type	Sulphate of ammonia rates					Superphosphate rates					Muriate of potash rates				
			Nil yield	Difference due to 1 cwt	1½ cwt	2 cwt	3 cwt	Nil yield	Difference due to 1 cwt	1½ cwt	2 cwt	3 cwt	Nil yield	Difference due to ½ cwt	¾ cwt	1 cwt	1½ cwt
1948†	*Abakaliki Farm*	2^4	9876		+ 121			8899		+2075**			9771		+ 331		
1948	,,	3^3	10147		+1836*		+1512*	9912		+1557*		+2486*	10091		+1725*		+1781
1948	,,	3^3	9150		+2408*		+2677**	9038		+1859**		+3561**	10494		+ 605		+ 448
1947	*Ezza*	*Basal* (+N)	2132		+1418*		+2264**										
1948	,,	2^4	3877		+1229**			3680		+1624***			4600		— 216		
1948	*Ake-Eze*	3^3	8450		+1106		+ 619	8174		+1144		+1416	9050		+ 441		— 536
1948	*Ikwo*	3^3	3941		+1286**		+1054**	4757		+ 82		— 187	4359		+ 754*		+ 332
1950	*Isieke*	3^3	7170	+1560		+1900*		7500	+ 820		+1600		8430	+ 250		— 770	
1951	*Okposi*	3^3	1976	+ 657		+ 963*		4961		+ 696		963*	5153	+ 398		+ 685	

Table 2. Owerri province, yam fertilizer effects

Year	Expt type	Sulphate of ammonia rates						Superphosphate rates					Muriate of potash rates				
		Nil yield	Difference due to ¾ cwt	1 cwt	1½ cwt	2 cwt	3 cwt	Nil yield	Difference due to 1 cwt	1½ cwt	2 cwt	3 cwt	Nil yield	Difference due to ½ cwt	¾ cwt	1 cwt	1½ cwt
Umuahia farm																	
Umudike																	
1947	3^3	9451	+ 739		+ 267			10045	— 374		— 425		8932	+ 980*		+1582**	
1949	3^3	5035		+ 264		+ 875		5405	+ 15		+ 105		4427	+1328*		+ 731*	
1950	3^3	6193		+ 689		+ 913*		6765	+ 336		— 267		6399	+ 695		+ 291	
Isoba																	
1948	3^3	4387			+ 624		+1428**	5033		+ 204		— 90	5060		— 27		+ 59
1950	3^3	6928		+ 543		+2201**		7751	+ 30		+ 244		7767	— 234		+ 461	
1951	3^3	5128		+ 316		+ 720		5692	+ 562		— 94		5171	+ 503		+ 403	
Obohia																	
1948	3^3	5376			+ 685		+1957**	6166		+ 496		— 2	6559		— 543		— 363
1951	3^3	6013		+1711*		+2191*		7340	— 45		— 33		6951	— 685		+ 404	
1950	3^3	5471		+ 707*		+ 901*		5804	+ 560		+ 59		5517	+ 596		+ 885*	
Owerri																	
1948	3^3	5158			+ 685		+1283	5705		+ 42		+ 342	5795		+ 48		+ 95
1948	3^3	2970			+ 760***		+1482***	3653		+ 79		+ 112	3670		— 18		+ 160
1950	3^3	3727		+ 157		+ 636		4018	— 562		+ 483		3900	— 257		+ 53	
1950	3^3	3665		+ 470		+ 893		4012	+ 136		+ 166		3940	+ 87		+ 451	
Miscellaneous																	
1948 (*I.N.*)	2^4	3215			+ 846*			3245		+ 786*			3594		+ 88		
1948 (*Amigbo*)	2^4	4905			+ 786			5326		— 56			5056		+ 504		

† Two replications analysed as one experiment.
* Significant differences.

Onitsha province

1947—Two experiments were laid down, one a single replication of a 3^3 at Nnewi near Onitsha and the other a randomized block arrangement identical to the Ezza experiment in Ogoja to ascertain the effect of nitrogen at Awka. The nitrogen levels were the same in both experiments, being $1\frac{1}{2}$ and 3 cwt of sulphate of ammonia per acre. The phosphate and potash levels were respectively $1\frac{1}{2}$ and 3 cwt superphosphate and $\frac{3}{4}$ and $1\frac{1}{2}$ cwt muriate of potash per acre. The time of application was, as in the other 1947 experiments, phosphate and potash before planting and nitrogen in two equal amounts after germination reached 50 per cent.

1948—The number of experiments was increased to five consisting of four 2^4 and one 3^3 layout. The single replication of the 3^3 was at Ikouka near Nsukka and the 2^4 at Oku, Ozubula, Ihialla and Agbanni. The Agbanni experiment was discarded due to extreme variation in stand. The rate of application of all fertilizers for the 3^3 was the same as in the previous year and the rates for the 2^4 factors were the same as the first level of the 3^3 layout. The method of application for all experiments was the same as in 1947.

1949—The number of experiments decreased to two, a Latin square at Amanshi and a 2^3 on the provincial farm at Nkwelle near Onitsha. The latin square consisted of six treatments of sulphate of ammonia in $\frac{1}{2}$ cwt levels from zero to $2\frac{1}{2}$ cwt, with an overall dressing of 10 cwt lime, $1\frac{1}{2}$ cwt superphosphate and $\frac{3}{4}$ cwt of muriate of potash per acre. The 2^3 factorial was replicated eight times with treatments made up with 2 cwt sulphate of ammonia, 3 cwt superphosphate and 1 cwt muriate of potash. The method of application in the 3^3 was as in previous years, but the 2^3 had a split plot arrangement to compare the effects of broadcasting and placement of fertilizer, the results of which are not included in this report.

1950—There were three experiments, all single replications of a 3^3 and sited at Umuji, Nsukka and Isu. The rate of application of all fertilizing constituents was reduced, both sulphate of ammonia and superphosphate to 1 and 2 cwt per acre, and muriate of potash to $\frac{1}{2}$ and 1 cwt per acre. The method of application was by placement of all fertilizers at 60 per cent germination.

1951—The number of experiments was reduced to two, both of which were single replications of 3^3 and sited at Nsukka. The sites differed in that one had had an *Acioa* fallow and the other a grass fallow. The levels of superphosphate and muriate of potash were again changed, both being applied at $\frac{3}{4}$ and $1\frac{1}{2}$ cwt per acre. The method of application, however, remained the same, placement at 60 per cent germination.

The field results for Onitsha province are given in *Table 3*, compiled in the same manner as the previous tables.

Calabar province

1947—Two randomized block experiments each replicated five times and consisting of the following four treatments (*a*) nil, (*b*) basal dressing of 10 cwt lime, $1\frac{1}{2}$ cwt sulphate of ammonia and 1 cwt muriate of potash, (*c*) and (*d*) basal with $1\frac{1}{2}$ cwt and 3 cwt superphosphate per acre, were laid down to ascertain the phosphate effect. The results of these experiments

Table 3. Onitsha province, yam fertilizer effects

Year	Place	Expt type	Sulphate of ammonia rates					Superphosphate rates						Muriate of potash rates				
			Difference due to					Difference due to						Difference due to				
			Nil yield	1 cwt	1½ cwt	2 cwt	3 cwt	Nil yield	¾ cwt	1 cwt	1½ cwt	2 cwt	3 cwt	Nil yield	½ cwt	¾ cwt	1 cwt	1½ cwt
	Nsukka																	
1948	*Bush*	3^3	3339		+ 994***		1629***	4429			— 395		— 276	4000		+ 300		+ 342
1951	Acioa	3^3	4791	+2625***		+3417***		6762	+ 237		— 108			6325	+ 535		+ 906	
1950	*Grass*	3^3	4721	+ 463		+ 658		4475		+1028**		+ 802		4767	+ 794*		+ 188	
1951	*Grass*	3^3	6256	+1885***		+1009*		6664	+ 542		+1153**			6554		+1153**		+ 848*
	Awka																	
1948	*Oku*	2^4	3068		+1089***			3808			— 392*			3288		+ 649***		
1949	*Awka*	*Basal*																
		+N	4938		+1564**		+2442**											
1950	*Isu*	3^3	4549	— 37		+ 493		4481		+ 395		+ 279		4473	+ 226		+ 471	
	Onitsha																	
1947	*Nnewi*	3^3	2517		+1439***		+1615***	3475			+ 118		+ 115	3381		+ 338*		+ 178
1948	*Ihialla*	2^4	3494		+ 606**			3192			— 4			2891		+ 400		
1948	*Ozubulu*	2^4	3088		+ 850**			3560			— 69			3640		— 255		
1949	*Nkwelle*	*R.B.*	4737			+1293***		5276					+ 215	5123			+ 521	
1949	*Amanshi*	*L.S.*	3774	+2960	+4580***	+3024**												
1950	*Umuoji*	3^3	3675	— 400		+ 391		3435		+ 309		+ 363		2950	+ 914*		+1213*	
1948	*Agbani*	3^3	4110			+1493**												

Table 4. Calabar province, yam fertilizer effects

Year	Place	Expt type	Sulphate of ammonia rates					Superphosphate rates			Muriate of potash rates		
			Difference due to					Difference due to			Difference due to		
			Nil yield	¾ cwt	1 cwt	1½ cwt	2 cwt	Nil yield	1 cwt	2 cwt	Nil yield	½ cwt	1 cwt
1948	*Uyo*	3^3	5013	+1097		+1008		6130	— 940	— 306	5303	+ 519	+ 715
1948	*Opobo*	3^3	3090	+1644**		+2570		4163	+ 455	+ 539	4283	+ 345	+ 289
1948	*Austin Akpo*	3^3	6480	+1061		+1033		7591	— 900	— 339	6723	+ 615	+ 650
1950	*Obio Akpa*	3^3	5522		+ 223		+ 760	5523	+ 421	+ 563	5503	+ 427	+ 607
1950	*Uyo*	3^3	3768		+ 578		— 315	3857	+ 84	— 96	3770	+ 273	— 17
1951	*Ediene*	3^3	3330		+ 515*		+ 445*	3764	— 212	— 94	3366	+ 127	+ 124
1951	*Ikot Ekpene*	3^3	2505		+ 350		+ 454	2645	+ 85	+ 299	2668	+ 112	+ 290

* Significant differences.

are not indicated in the results table for Calabar province and it is pertinent to mention here that the basal dressing gave highly significant increments of over a ton and a half of tubers per acre with additional phosphate applications tending to lower the increment.

1948—Five experiments, two 2^4 and three 3^3, were laid down. Both the 2^4 sited at Arochuku and Calabar had to be abandoned due to an extremely variable previous cropping history, *i.e.* bush fallow within the site ranging from one to three years and parts of the area entering the second cycle of cropping. The two levels of the 3^3 experiments, which consisted of single replications at Opobo, Uyo and Oron, were sulphate of ammonia $\frac{3}{4}$ and $1\frac{1}{2}$ cwt, superphosphate 1 and 2 cwt and muriate of potash $\frac{1}{2}$ and 1 cwt per acre. The crop at the Oron site was a failure, the average yield being less than a ton to the acre, which was due primarily to a severe drought and partially to poor planting material. In accordance with the practice at the time, superphosphate and muriate of potash were applied, before planting, to the half-made ridges and sulphate of ammonia as a top dressing in two portions after general germination.

1949—The experimental programme did not include fertilizer work on yams in this particular year.

1950—Two yam fertilizer experiments consisting of simple replications of 3^3 were laid down, one on the provincial farm at Obia Akpa near Abak and the other at Uyo approximately 11 miles away. The rates of application were the same as in 1948 except that sulphate of ammonia was increased to 1 and 2 cwt per acre. All fertilizers were applied as a placement dressing at 60 per cent germination.

1951—Again two experiments made up of single replications of a 3^3 were laid down in the province, one at Ikot Ekpene and the other at Edienne near Abak. There were no changes in the nature or the method of application from the 1950 experiments.

The yield results for Calabar province are presented in *Table 4.*

DISCUSSION

There are very few experiments in any province that can be combined due to the variation in rate of application of particular fertilizers during the period under consideration. The yield results have been compiled into tables for each province, and are grouped into like areas for comparison. Significant effects have been denoted by asterisks. In certain cases where results approach significance and for practical purposes can be considered significant then they too have been marked with an asterisk for the 5 per cent level.

The results will be discussed first on the general overall response in the region, and then on a provincial basis.

Nitrogen effect

General—The response to sulphate of ammonia is marked throughout the region. There were 47 experiments in all, with a total of 82 applications, which, with two exceptions, produced yield increases. Of the increases 43 were significant and a further 22 can be considered as such for practical purposes, in view of the almost 100 per cent positive trend. The overall

results indicate that nitrogen is a limiting factor and is required throughout the region.

Provincial—The provincial responses vary and are illustrated by the calculated increase (round figures) due to sulphate of ammonia shown in *Table 5*.

Table 5. Sulphate of ammonia response, yam tubers lb./acre

Sulphate of ammonia in	1 cwt	1½ cwt	2 cwt
Ogoja province	1000	1500	1550
Onitsha province	1150	1500	1500
Owerri province	575	750	1100
Calabar province	850	1000	550

In Ogoja province all applications of sulphate of ammonia produced increases, of which 12 out of the 16 can be considered significant. The heavier dressings of 2 cwt and over do not consistently produce increased yield over the 1½ cwt application, which appears to be adequate for the area.

In every case in Owerri province yields were increased by the applications of sulphate of ammonia. The response on the provincial farm at Umudike is of a much lower order than the rest of the province and can, no doubt, be attributed to the cultural practice of manuring and crop rotation normally followed on a Government farm. The response in the province is generally to the heavier dressings as shown by nine cases of significance in the higher rates of application against two in the lower rates of application. This tendency is further illustrated in the calculated response shown in *Table 5*.

There were two non-significant decreases in yield due to sulphate of ammonia in Onitsha province, while practically all the remaining 22 applications produced significant increases. As in Ogoja province, the heavier dressings do not produce correspondingly higher yields and the same rate of 1 to 1½ cwt per acre of sulphate should be adequate.

There were only seven experiments during the period in Calabar province. The evidence is indeed meagre but a trend is indicated in favour of sulphate of ammonia at the lower rates of application.

Phosphate effect

General—There is no general overall response to the application of phosphate fertilizers in this region.

Provincial—In Ogoja province, there is a definite need for phosphates especially on the provincial farm at Abakaliki. The four experiments sited on the farm show significant increases for applications of superphosphate; the response to the higher rates of application is quite marked and agrees with results from rice experiments on the farm, indicating the area to be generally low in available phosphate[5]. The other experiments in the province are quite scattered and the results variable; however, it will be noted that there is only one depression in yield which is of a low order, *i.e.* 187 lb. per acre, while the eight increases, with one exception, are quite marked.

In Owerri and Calabar and all parts of Onitsha province, with the exception of the Nsukka area, the response from applications of superphosphate is extremely variable with almost as many depressions in yields as there are increases. In the Nsukka area, where there was a grass fallow preceding the crop, there was a substantial and significant increase in yield of tubers for two consecutive years from applications of superphosphate. These results indicate a trend in this area, but further investigation is required.

Potash effect

General—There is a general overall response throughout the region to the lower applications of muriate of potash. This trend is definite in all provinces with the exception of Owerri province. The calculated increase (round figures) to units of muriate or potash by provinces is given in *Table 6*.

Table 6. Muriate of potash response, yam tubers lb./acre

Muriate of potash in	½ cwt	¾ cwt	1 cwt
Ogoja province	600	675	475
Onitsha province	525	625	625
Calabar province	300	325	325
Owerri province	170	200	300

In connection with the potash response it is pointed out that the muriate of potash used in these experiments was high grade (60 per cent K_2O) and consequently the units of K_2O applied per acre were high. It would have been more advisable, from the trend point of view, to have used a lower analysis potash carrier or to have used lower rates of application of the muriate.

Provincial—The response to potash is more marked on the provincial farms in Ogoja province than on the out-station sites. Although there are only two cases of significance in the province, it will be noted that the first level in every case produced increases in yield of tubers and that further applications produced no further increases but in fact tended to decrease the original increment.

There was considerable variation in the potash response in Owerri province but the overall trend is for a slight increase in yield from applications of muriate of potash. On the provincial farm at Umudike, there is a definite and positive response as shown by the significant increases in yield of tubers. Response to potash has also been noticed in maize crops on the provincial farm[5]. This response to potash at Umudike can probably be linked with the system of rotation which does not include bush fallows which, with native farming practice, are subsequently burnt thus leaving considerable available potash in the ash.

Onitsha province showed the most marked overall response to potash. There were eighteen applications which, as shown in *Table 3*, produced one non-significant depression, and 17 increases ranging from 226 to 1,213 lb., seven of which were significant. The significant increase at Umogi of 1,213 lb. of tubers, compared with the markedly lower increment in the same area for that and previous years, was investigated. It appears that the bush cover in this particular experiment was considerably poorer in many respects

than on the other sites. It will also be noted that with yams there is a considerable response to potash on the provincial farm at Nkwelle, where a bush fallow does not form part of the rotation. Onitsha province as a whole has been more heavily farmed than other provinces and the greater response to potash may be attributed to the generally poorer bush cover.

Although there is very little data available for Calabar province, the results indicate a slight response to potash. The increases are not of the same order as in the other provinces but the trend is the same, a general increase for first level of application with the second level tending to produce a reduction from the original increment.

The marked potash response on the provincial farms at Umudike, Abakaliki and Nkwelle are, in the author's opinion, due to the rotation system which does not include a bush fallow. The burning of a bush fallow immediately before land preparation does mean that the available potash in the wood ash is incorporated into the soil and thus possibly explains the lower potash response on farmers' land than the provincial farms. It is the author's opinion that, due to the greater need for land and increased population, the quality of the bush fallows will deteriorate as the length of the bush fallow is reduced (a fallow of four to five years is now common in areas where it was formerly eight to ten years); and thus in the future there will be a greater response to potash.

SUMMARY

The experimental programme on fertilizers for the yam crop over the 1947–51 period is described. Various problems arising from out-station experiments in undeveloped country with poor communications are discussed. In general, there is a marked response to nitrogen, and also to potash but at a much lower order, throughout the region. There is not a general response to phosphate throughout the region but in certain areas there are definite positive trends.

(*Received October 1955*)

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Book Reviews

MINERAL NUTRITION OF FRUIT CROPS

N. F. Childers (Ed.). Horticultural Publications: New Brunswick. 907 *pp.* (illus.)

This large volume is the work of twenty-eight contributors and deals with the mineral nutrition of a range of fruit crops. Separate chapters deal in alphabetical order with the apple, avocado and mango, blueberry and cranberry, bush fruits, cherry, citrus, grape, edible nuts, peach, pear, plum prune and apricot, strawberry and tung; the aim, as expressed by the editor, being to present the most up to date research information for the grower, research worker, agricultural teacher, extension worker and others.

The book is certainly a mine of information but would be beyond the average fruit grower unless he were a trained scientist. Moreover, few teachers or extension workers could spare the time to separate the salient features from the mass of experimental results, often conflicting, that have been assembled. If the research worker were interested in only one or two of the crops the relevant chapters would be most useful. If, however, he were interested in the more fundamental aspects of mineral nutrition a long search would be necessary to discover any coherent theories.

The book would have been better planned if the individual mineral nutrients had formed the basis of each chapter. Nitrogen nutrition for example could be dealt with in its general aspect and any differences in response between the crops contrasted. Base antagonism and leaf analysis instead of being dealt with rather briefly for each crop could be treated in the same way. This approach is used in one chapter on the use of chelated metals. The point is that nutrition is mainly a function of soil and fertilizer. If a soil is deficient in magnesium all fruit crops growing on it might be expected to suffer from magnesium deficiency and methods of controlling it would in general be similar.

Two chapters deal with isotopic tracers and field experimentation. Both are very sketchy and add little to the value of the book. The photographs illustrating mineral deficiency symptoms occupy some 130 pages and these are grouped logically by minerals rather than by crops. The standard of reproduction is in general good but the use of colour would have added appreciably to their value.—D.B.M.

THE NATURAL HISTORY OF TSETSE FLIES

P. A. Buxton, London School of Hygiene and Tropical Medicine, Memoir No. 10. H. K. Lewis & Co.: London, 1955. xviii + 816 *pp.*, 47 plates, 165 text figures. £4 4*s* 0*d*

It is almost twenty years since the publication of C. F. M. Swynnerton's monograph on the Tsetse Flies of East Africa (*Trans. R. Ent. Soc.* **84,** 1936), since when a great deal of additional information has been obtained by

numerous workers in this field. Professor Buxton has had a wide, if not detailed, experience of the tsetse and trypanosomiasis problems, having visited on various occasions most of the countries in Africa where ' fly ' is prevalent. The author is therefore eminently capable of selecting the most interesting and important facts from the somewhat voluminous literature that has accumulated, though it should be added that nearly all the recent work on tsetses has been of a very high standard.

In addition to covering all aspects of the natural history of tsetses the book contains chapters on control, and on tsetses in relation to trypanosomiasis. The book is excellently produced and most adequately indexed by W. H. Potts. Agricultural officers in Africa, though they can scarcely be expected to read the whole book, are strongly advised to look up the references to ' Agriculture ', ' Cultivation ' and ' Erosion '.—T.W.K.

ECONOMIC GEOGRAPHY OF WEST AFRICA

F. J. Pedler. Longmans Green & Co.: London, 1955. xii + 232 *pp.* (illus.) 16*s*

This is a most stimulating text book written from intimate knowledge of the territories and completely up-to-date. Three chapters deal wholly with agriculture, and several others indirectly concern it. The reader will learn many facts which are not easily available outside obscure annual reports, for example that the operations of the Gonja Development Co. at Damongo in the Gold Coast have proved much more expensive than expected, and consequently settlement has been restricted to a small pilot scheme. Some interesting glimpses are given of the manifold but little-known activities of the Regional Production Development Boards in Nigeria. In several passages the author is over-concerned to justify the operations of trading companies in West Africa.—G.B.M.

THE FORESTER'S COMPANION

N. D. G. James. Basil Blackwell, Oxford, 1955. 312 *pp.* (illus.) 12*s* 6*d*

At the commencement of Part II of a working plan all foresters state the ' Objects of Management ', similarly in the first paragraph of the preface the author states the ' Objects of Compilation '. Unlike foresters whose success in attaining their objects can seldom be judged for several or many decades it is at once obvious that the author has successfully attained his ' objects ' and has produced an excellent ' ready source of information which fits into the pocket ', in value it is also extremely light on the pocket.

The arrangement and layout are good, the ground covered is comprehensive and the usefulness of the book enhanced by the author's references to works which deal more fully with the subject than a book of this size could possibly do.

To the tropical forester the details of many of the subjects dealt with are of academic interest only, yet underlying each chapter are the principles, systems and organization of forestry which form the common basis of all sound forestry practice and which are independent of climate or geographic region.

The trained forest officer in the tropics will welcome this book as a source of reference for many of the problems which confront him from time to time and for which there is no adequate field reference book. The author has therefore earned the gratitude of foresters in the tropics, although the book was written for their colleagues in the United Kingdom.—D.M.

TANGANYIKA: A REVIEW OF ITS RESOURCES AND THEIR DEVELOPMENT

Prepared by J. F. R. Hill and edited by J. P. Moffett. Government of Tanganyika, 1955. 924 *pp.*, with maps and charts. £2 2*s*

This massive volume has been prepared by the Tanganyika Government as a background to development plans. It is stated in the foreword that most of the sections have been contributed by the heads of the departments concerned. The relevant parts for the agriculturist are Part V, on the fundamental factors of production which covers land tenure, soils, and tsetse work, and Part VI, which includes agriculture and livestock. For the presentation of the data in such a convenient form all students of African agriculture must owe gratitude, only slightly diminished by the fact that the book was prepared in 1951-2, and the latest statistical figures only refer to 1952.

Here are to be found the history, problems, and production figures of all the agricultural industries of the territory. The section on livestock is particularly good, especially the description of the animal disease situation, of which a comprehensive picture can never be obtained from single annual reports of the department concerned. The facts presented, and the interesting suggestions made from them, will prove stimulating to several different classes of readers. A table on page 601 shows that, as the milk yields of a herd of zebu cows at the Mpwapwa breeding station were increased, butterfat content went down. There are other indications in the tropics that butterfat content is highest where milk yields are lowest. Could it be that the high cream content of tropical milk is in part connected with the low total volume of the liquid ? (This naïve suggestion is the reviewer's, not the book's!)

The book is, for anyone concerned with African agriculture, remarkably good value for money by present standards.—G.B.M.

PROCEEDINGS OF THE SECOND INTER-AFRICAN SOILS CONFERENCE, LEOPOLDVILLE 1954. VOL. I AND II

Ministry of Colonies: Brussels, 1955. 1,544 *pp.* £4 6*s* 6*d*

The proceedings of the Leopoldville conference are not to be taken as an isolated event, since it constituted the second in a series which began at Goma in 1948. The record therefore begins with reports to the conference on the progress achieved in the interval; a substantial attainment, since it includes the setting up of the Inter-African Bureau for Soils, the Inter-African Pedological Service, and the Regional Committees for South, Central, and West Africa—though that for East Africa was still unfortunately lacking. Most readers of this journal will know of our contemporary

African Soils, now in its third volume, which is a product of the Inter-African Bureau for Soils; they may not know that this Bureau added to its title the words ' and Rural Economy ', giving it a wider scope, some two years ago.

Turning to the future, the conference passed a series of 17 resolutions, mostly recommendations to the African governments on policy to be pursued in the study, utilization, and conservation of soils. These are something more than the pious platitudes usually emitted by conferences, many of them being fairly specific, for example, the call for greater study of the tropical black clays or the prevention of erosion along cattle tracks.

The bulk of the two volumes is taken up by printing the 120 papers presented to the conference. Critical evaluation of such a miscellany of information is difficult. It is obviously of uneven value. First announcements of the results of original research are nowadays seldom made to conferences, but a number of the papers are of great value in surveying the contemporary state of progress in soil studies and utilization in some particular territory. One contribution by Dr Vine has a particularly intriguing title, ' Is the lack of fertility of tropical African soils exaggerated ? ', and may stimulate some useful thought.

The proceedings are printed in English and French; the papers in English or French, with a summary in the other language.—G.B.M.

Recent Publications of The Imperial College of Tropical Agriculture

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Reprints are available, at varying prices, of articles in the Cacao Research Reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao (1945–1951 Report)—Price 5*s* plus postage.

Memoirs—Economic Series No. 2: Peasant Farming: Report on Peasant Experimental Farms at the Imperial College of Tropical Agriculture, Trinidad, B.W.I., by A. L. JOLLY. 1*s*

Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the second world war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

Volume I Ranunculaceae to Araliaceae complete in eight parts and index. 26*s* 6*d*

Volume II Part 1. Rubiales. 2*s*

Part 2. Asterales to Primulales. 3*s* 6*d*

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Part 6. Verbenaceae and Labiatae, in the press.

Further parts are in preparation.

These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.

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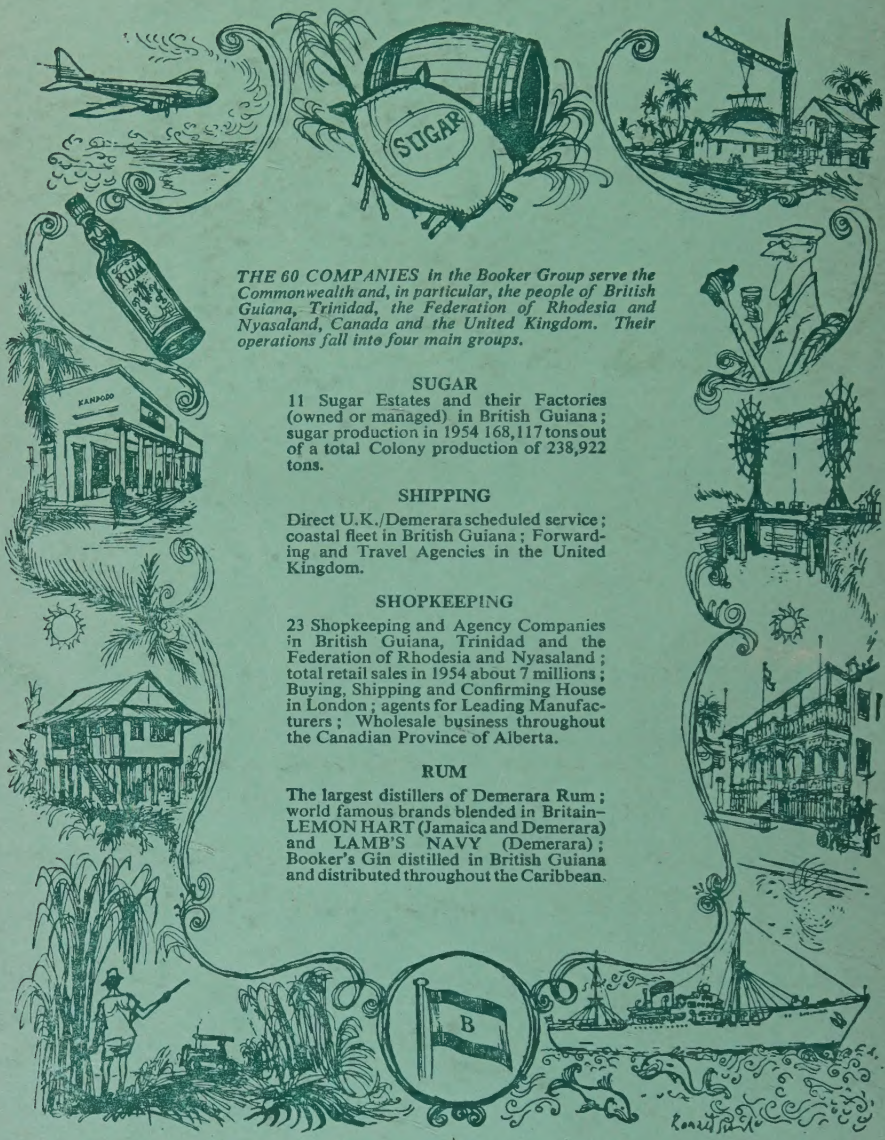

THE 60 COMPANIES in the Booker Group serve the Commonwealth and, in particular, the people of British Guiana, Trinidad, the Federation of Rhodesia and Nyasaland, Canada and the United Kingdom. Their operations fall into four main groups.

SUGAR

11 Sugar Estates and their Factories (owned or managed) in British Guiana; sugar production in 1954 168,117 tons out of a total Colony production of 238,922 tons.

SHIPPING

Direct U.K./Demerara scheduled service; coastal fleet in British Guiana; Forwarding and Travel Agencies in the United Kingdom.

SHOPKEEPING

23 Shopkeeping and Agency Companies in British Guiana, Trinidad and the Federation of Rhodesia and Nyasaland; total retail sales in 1954 about 7 millions; Buying, Shipping and Confirming House in London; agents for Leading Manufacturers; Wholesale business throughout the Canadian Province of Alberta.

RUM

The largest distillers of Demerara Rum; world famous brands blended in Britain—LEMON HART (Jamaica and Demerara) and LAMB'S NAVY (Demerara); Booker's Gin distilled in British Guiana and distributed throughout the Caribbean.

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